Trilogy Service Manual Update

For Software Version 1.5

PN: A-61-TOSMA-0-0

TRILOGY™

Multichannel Infusion Pump

Service Manual

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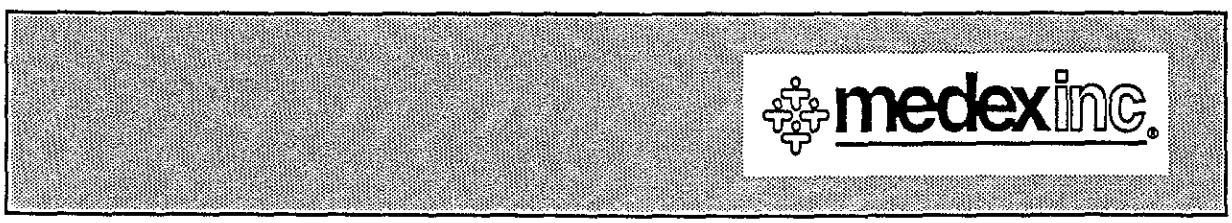

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Section 1.0
Pump Operation

1.1

Biomed Menu

The Biomed menu includes 11 modes which are accessible via the control panel.

The modes are:

1. Check/Clear Error Codes - Displays error codes for the last SYSTEM CHECK alerts.
2. Pressure Cal - Calibrates the BOTTLE OCCLUSION and the fixed PATIENT OCCLUSION alert sensitivity.
3. Air Detect Cal - Calibrates the AIR IN CASSETTE alert sensitivity.
4. Volumetric Cal - Adjusts the volumetric calibration of the channels.
5. Enter Cal Constant (not used)
6. Check Cal Data - Displays various calibration factors.
7. Set Max Pressure - Overrides the user adjustable pressure limit and sets the PATIENT OCCLUSION alert pressure to maximum.
8. Manual Operation - Overrides various alert conditions and allows the pump modules to be run manually.
9. Keypad Check - Checks the continuity of the control panel switches.
10. Bat Cal Valid - Allows the service technician the ability to validate the previous battery calibration following the disconnection of the battery.
11. Last Bat Cal - Displays the number of days since the last battery calibration.

Note: For software version 1.3 only modes 1 through 9 are available.

To Access The Biomed Menu:

To access the Biomed menu:

1. Press the POWER key to turn on one channel (only one channel may be on).
2. Press SELECT OPTION and ADJUST OPTION simultaneously. *ENTER CODE AND PRESS ADJUST* will scroll across the display.
3. Enter the access code *663.5* in the FLOW RATE display.
4. Press ADJUST OPTION. *BIOMED MODE - NOT FOR CLINICAL USE* will scroll across the display.

After entering the Biomed mode, press SELECT OPTION until the desired mode is scrolled across the display. Press ADJUST OPTION to enter the mode.

To Exit The Biomed Menu:

To exit the Biomed menu, press the POWER key to turn off the channel.

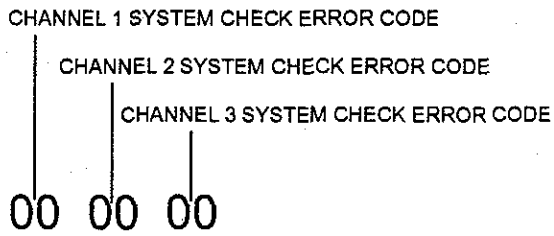
1. Check/Clear Error Codes

The Check/Clear Error Codes mode displays the error code for the last detected CHANNEL SYSTEM CHECKS, COMMON SYSTEM CHECKS,and the operation state of the I^2C bus at the point in time that a COMMON SYSTEM CHECK occurred.

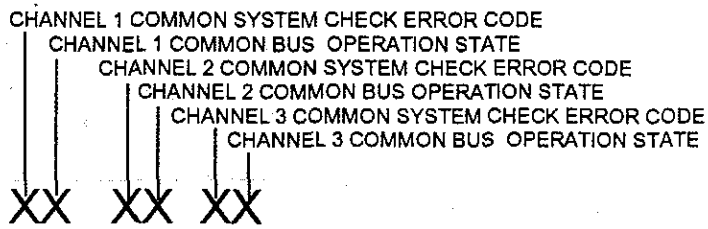
To check the error codes, access the Biomed menu and press SELECT OPTION until *1.CHECK/CLEAR ERROR CODES* scrolls across the display.

A set of six digits alternating with a set of six characters will be displayed in the TOTAL INFUSED display.

The six digits display the CHANNEL SYSTEM CHECK error codes as follows:



The six characters display the COMMON SYSTEM CHECK error codes and the common bus operation state as follows:


CHANNEL 1 COMMON SYSTEM CHECK ERROR CODE
CHANNEL 1 COMMON BUS OPERATION STATE
CHANNEL 2 COMMON SYSTEM CHECK ERROR CODE
CHANNEL 2 COMMON BUS OPERATION STATE
CHANNEL 3 COMMON SYSTEM CHECK ERROR CODE
CHANNEL 3 COMMON BUS OPERATION STATE
XX XX XX

There are some instances when only the error codes for one channel are displayed. This is related to interruptions on the common bus.

Refer to pages 4-8 through 4-11 for definitions of the codes for the CHANNEL SYSTEM CHECK, the COMMON SYSTEM CHECK, and the common bus operation state.

To clear error codes, press ADJUST OPTION while the COMMON SYSTEM CHECK error codes are displayed or when prompted by a message scrolled across the display.

2. Pressure Cal

The Pressure Cal mode adjusts the BOTTLE OCCLUSION alert and the fixed PATIENT OCCLUSION alert sensitivity.

The BOTTLE OCCLUSION alert activates when a pressure of -8 to -13 InHg is present in the bottle side line, and the fixed (maximum) PATIENT OCCLUSION alert activates when a pressure of 10 to 15 PSI is present in the patient side line. Reference sections 2.3 and 2.4 for further information regarding these alert conditions.

Note: Prior to performing this calibration operate the channel with a primed cassette at a rate of 600 ml/hr for at least 2 minutes. This exercises the rubber membranes.

To perform the pressure calibration, access the Biomed menu and press SELECT OPTION until *2.PRESSURE CAL* scrolls across the display. When *NO* appears in the display, press ADJUST OPTION. *YES* will appear in the display and the calibration will be initiated. If a cassette is loaded and the cassette door is closed the unit will prompt you to open the cassette door. *WAIT* will appear in the display while the calibration proceeds. Upon completion of the calibration one of the following messages will be displayed:

CAL COMPLETE - Successful calibration.

INVALID OP LIMIT (XXXX) - REPEAT CAL - This indicates that the fixed PATIENT OCCLUSION alert could not be calibrated. XXXX is the invalid OP threshold displayed in A/D counts.

INVALID UP LIMIT (XXXX) - REPEAT CAL - This indicates that the the BOTTLE OCCLUSION alert could not be calibrated. XXXX is the invalid UP threshold displayed in A/D counts.

INVALID NEG VANE EDGE (XXX) - REPEAT CAL - This indicates that the timing relationship between the peak of the transducer pressure curve and the motor position is not correct. XXX is the invalid motor step location of the NEG vane edge.

INVALID POS VANE EDGE (XXX) - REPEAT CAL - This indicates that the timing relationship between the peak of the transducer pressure curve and the motor position is not correct. XXX is the invalid motor step location of the POS vane edge.

Note: Early versions of software did not display the invalid values.

3. Air Detect Cal

The Air Detect Cal mode adjusts the AIR IN CASSETTE alert sensitivity.

When adjusted by this mode, the AIR IN CASSETTE alert activates when 20 to 100 micro-liters of air is trapped in the cassette. Reference section 2.5 for further information regarding the AIR IN CASSETTE alert.

Note: Prior to performing this calibration operate the channel with a primed cassette at a rate of 600 ml/hr for at least 2 minutes. This exercises the rubber membranes.

To perform the air detect calibration, insert a properly primed cassette, with the solution container approximately 24 inches above the cassette, into the channel and close the cassette door. Open the roller clamp.

Note: All the air must be purged from the cassette. Air trapped in the cassette will cause the air detect point to be incorrect or will cause an error message at the end of this calibration.

Access the Biomed menu and press SELECT OPTION until *3.AIR DETECT CAL* scrolls across the display. When *NO* appears in the display, press ADJUST OPTION. *YES* will appear in the display and the calibration will be initiated. *WAIT* will appear in the display while the calibration proceeds. Upon completion of the calibration one of the following messages will be displayed:

CAL COMPLETE - Successful calibration.

INVALID AIR DETECT PT (XXX) - REPEAT CAL - This indicates that the rate of pressure increase between the refill and delivery cycles is out of range. XXX is the invalid motor step location for the air detect point.

Note: Early versions of software did not display the invalid values.

4. Volumetric Cal

The Volumetric Cal mode calibrates the volumetric flow rate of the pump.

When calibrated by the Volumetric Cal mode, the volumetric accuracy is approximately +/- 1% under the standard conditions listed below. However, the accuracy specification for the pump is +/- 5% under the following standard conditions.

- Container height 24" above the cassette.
- Infusing via a straight IV administration set (not a burette or filter set) such as: IV1A01, IV1L01, IV1A02, IV1A03, IV1A04, IV1A08.
- Infusing through a 18 gauge needle at a flow rate of 600 ml/hr into an open container.
- Infusing a non viscous fluid which is free of air.

To perform the volumetric accuracy calibration, insert a properly primed cassette, with the solution container approximately 24 inches above the cassette, into the channel and close the cassette door. Open the roller clamp. Insert the distal end of the IV set into a volumetric measurement device.

Note: Prior to performing this calibration operate the channel with a primed cassette at a rate of 600 ml/hr for at least 2 minutes. This exercises the rubber membranes.

All the air must be purged from the cassette. Air trapped in the cassette will cause the volumetric accuracy to be adjusted incorrectly or will cause an error message at the end of this calibration.

Access the Biomed menu and press SELECT OPTION until *4.VOLUMETRIC CAL* scrolls across the display. When *NO* appears in the display, press ADJUST OPTION. *YES* will appear in the display followed by *PRESS INFUSE.* Press INFUSE/PAUSE. The unit will deliver 20.0 ml of fluid. *ENTER MEASURED VOL IN VTBI AND PRESS ADJUST* will scroll across the display. Enter the volume of fluid measured into the VOLUME

TO BE INFUSED display and press ADJUST OPTION. *WAIT* will appear in the display while the calibration proceeds. Upon completion of the calibration one of the following messages will be displayed:

CAL COMPLETE - Successful calibration

>5% ERROR,PRESS SELECT TO CANCEL OR ADJUST TO CONTINUE - This message indicates that the calibration constant based upon the volume measured is more than 5% greater than or less than the current calibration constant. However, the newly calculated calibration constant is still within acceptable limits.

Note: After the Bellows Assembly is replaced, it is normal to see this message during the initial calibration of the new Bellows Assembly. Press ADJUST OPTION to override the message and accept the new value.

INVALID VOL - REPEAT CAL - This indicates that the volume measured was not within the acceptable range.

5. Enter Cal Constant

The Enter Cal Constant mode is not to be used. If a value in this mode is inadvertently changed, perform the Periodic Maintenance Procedure, section 3.1.

6. Check Cal Data

The Check Cal Data mode displays the calibration constants.

OP is the fixed PATIENT OCCLUSION alert threshold and is in the range of 368 - 853 A/D counts. Each A/D count equates to 4.89 mv and the pressure transducer amplifier has a gain of 76 mv/psi and an offset such that 0 psi = 1 volt.

UP is the BOTTLE OCCLUSION alert threshold and is in the range of 0 - 512 A/D counts. Each A/D count equates to 4.89 mv and the pressure transducer amplifier has a gain of 76 mv/psi and an offset such that 0 psi = 1 volt.

NEG is the motor step with respect to the peak of the pressure curve at which the absolute position sensor makes a high to low transition. The absolute position sensor is triggered by the vane attached to the motor cam. The low end of the range is 395 and the upper end is 005. (Motor step 400 is followed by motor step 1).

POS is the motor step with respect to the peak of the pressure curve at which the absolute position sensor makes a low to high transition. It is 120 +/- 2 motor steps beyond NEG and is in the range of 113 to 127 motor steps.

ADP is the motor step at which the pressure curve is checked to determine if air is present in the cassette. The range is 107 - 125 motor steps.

Reference sections 2.3, 2.4, and 2.5 for further information.

sure mode allows selection of the user adjustable
SION pressure limit or the maximum (fixed) PATIENT

TIENT OCCLUSION limit, access the Biomed menu and
'TION until *7.SET MAX PRESSURE* scrolls across the
S or *NO* will appear in the display.

ars, press ADJUST OPTION and *YES* will appear. This
ATIENT OCCLUSION alert limit to maximum, 10 - 15 PSI,
es the user adjustable pressure limit.

ears, press ADJUST OPTION and *NO* will appear. This
ATIENT OCCLUSION alert limit to the user adjustable
nit.

8. Manual Operation

The Manual Operation mode allows the unit to operate with the PATIENT OCCLUSION, BOTTLE OCCLUSION, AIR IN CASSETTE, CASSETTE/DOOR, and some SYSTEM CHECK alerts disabled. This mode is useful for troubleshooting alert conditions which prevent the motor from operating. As an example, in order to monitor the output of the pressure transducer amplifier with an oscilloscope, the pump must be infusing. Yet, if there is an alert condition the normal operating mode will not allow the infusion to start, whereas in the manual mode the alert condition is ignored by the microprocessor and the infusion can be started.

Caution: Do not operate the pump in this mode with the roller clamp on the tubing set closed. This places unnecessary stress on the pumping mechanism.

To allow manual operation, access the Biomed mode and press SELECT OPTION until *8.MANUAL OPERATION* scrolls across the display. When *NO* appears in the display press ADJUST OPTION. *YES* will appear in the display and the channel will be in the manual mode. To exit the manual mode, power off the channel.

9. Keypad Check

The Keypad Check mode displays a numerical code when each of the control panel keys is pressed.

To check the keys, access the Biomed menu and press SELECT OPTION until *9.KEYPAD CHECK* scrolls across the display. When *NO* appears in the display, press ADJUST OPTION. *YES* will appear in the display.

The LOW BAT, DATA PORT, COMMON SYSTEM CHECK, and SYSTEM CHECK (CH1 or CH2 or CH3) indicators on the control panel will illuminate. If the LOCKOUT switch on the rear of the pump is pressed the LOCK indicator on the control panel will illuminate. The pump must be out of the lockout mode before proceeding.

Press each key, except QUIET ALARM, and a number will appear in the display which corresponds with the key as shown in the following table.

00 FLOW RATE TENTHS
01 FLOW RATE UNITS
02 FLOW RATE TENS
03 FLOW RATE HUNDREDS
04 TITRATE DOWN
05 TITRATE UP
06 VTBI TENTHS
07 VTBI UNITS
08 VTBI TENS
09 VTBI HUNDREDS
10 INFUSE ALL
12 TITRATE
13 CLEAR TOTAL
14 INFUSE/PAUSE
18 CHECK BAT
19 DISPLAY
20 ADJUST OPTION
21 SELECT OPTION
23 POWER

To exit this mode, press QUIET ALARM. *22* will be displayed followed by *BIOMED MODE-NOT FOR CLINICAL USE.*

10. Bat Cal Valid

After the battery charge circuit is opened, by disconnecting the battery fuse, battery, or Power Management Board, the software will require that battery be recalibrated when the battery circuit is reconnected.

The Bat Cal Valid mode allows the service technician the ability to validate the previous battery calibration following the disconnection of the battery.

Caution: Do not use mode if the battery is replaced. This would result in inaccurate battery operating messages.

To validate the previous battery calibration, access the Biomed menu and press SELECT OPTION until *10.BAT CAL VALID* scrolls across the display. When *NO* appears in the display press ADJUST OPTION. *YES* will now appear in the display and the previous battery calibration will now be valid.

11. Last Bat Cal

The Last Bat Cal displays the number of days since the last battery calibration.

To review the number of days since the last battery calibration, access the Biomed menu and press SELECT OPTION until *11.LAST BAT CAL* scrolls across the display. The number of days since the last battery calibration will be displayed.

Pump Operation

This section contains a copy of the current Trilogy operation manual for software version 1.3.

The current software is version 1.5. The primary difference between version 1.3 and 1.5 is that version 1.5 has two additional messages that can appear when the CHECK BAT key is pressed. These are:

BAT CAL NEEDED - This CHECK BAT message is displayed whenever 190 days have elapsed since the last battery calibration. The battery calibration is performed by fully charging the battery in the pump for 24 hours and then operating the pump on battery power until the Low Battery alert occurs.

REPLACE BAT - This CHECK BAT message is displayed when the battery operating time from full charge to the onset of the Low Battery alert is less than three hours, with all three channels pumping at 888.8 ml/hr.

Section 2.0
Theory of Operation

2.1

Overview

The fluid delivery system is comprised of the Trilogy infusion pump and various disposable I.V. administration sets that are available in a number of configurations. The system is designed to provide a qualified professional with a practical and safe means of delivering intravenous or intra-arterial fluid while controlling both the rate of infusion and the volume to be infused.

The mechanics of the fluid delivery system are contained in the Trilogy pumping module and the disposable cassette. The diagram shown in Figure 1 depicts the major components of the pumping mechanism.

The disposable cassette contains two pressure activated check valves and a fluid reservoir. The bottle side valve controls the inlet to the reservoir and the patient side valve controls the outlet from the reservoir. When the cassette is outside the pump, both valves are open allowing the tubing set to be primed via gravity flow. When the cassette is inserted into the pump, the valves are closed by two spring loaded actuators, thus stopping gravity flow.

The pumping action is created by the stepper motor turning the oval shaped cam which moves the rocker arm in an arc compressing the rear of the fluid filled bellows assembly. This in turn displaces the rubber membrane on the bellows assembly which displaces the membrane on the cassette. This action pushes the fluid from the cassette reservoir through the patient side valve into the tubing and to the patient. After approximately .2 ml of fluid is delivered to the patient, pressure within the cassette will decrease rapidly, due to the geometry of the cam, the bottle side valve will open and the fluid reservoir will be refilled with fluid from the fluid container.

The Trilogy incorporates three pumping modules each with independent microprocessors, power regulators, displays, and switches. This design minimizes the possibility that one component failure will stop the pumping action of all three I.V. lines. Common functions such as audio alerts, RS-232 interface, and inter-channel communications are shared by all channels and failure of these functions will not interrupt the pumping action of any of the channels. Figure 2 illustrates the various electronic controls within the pump.

Figure 1. Mechanical Pumping System Components

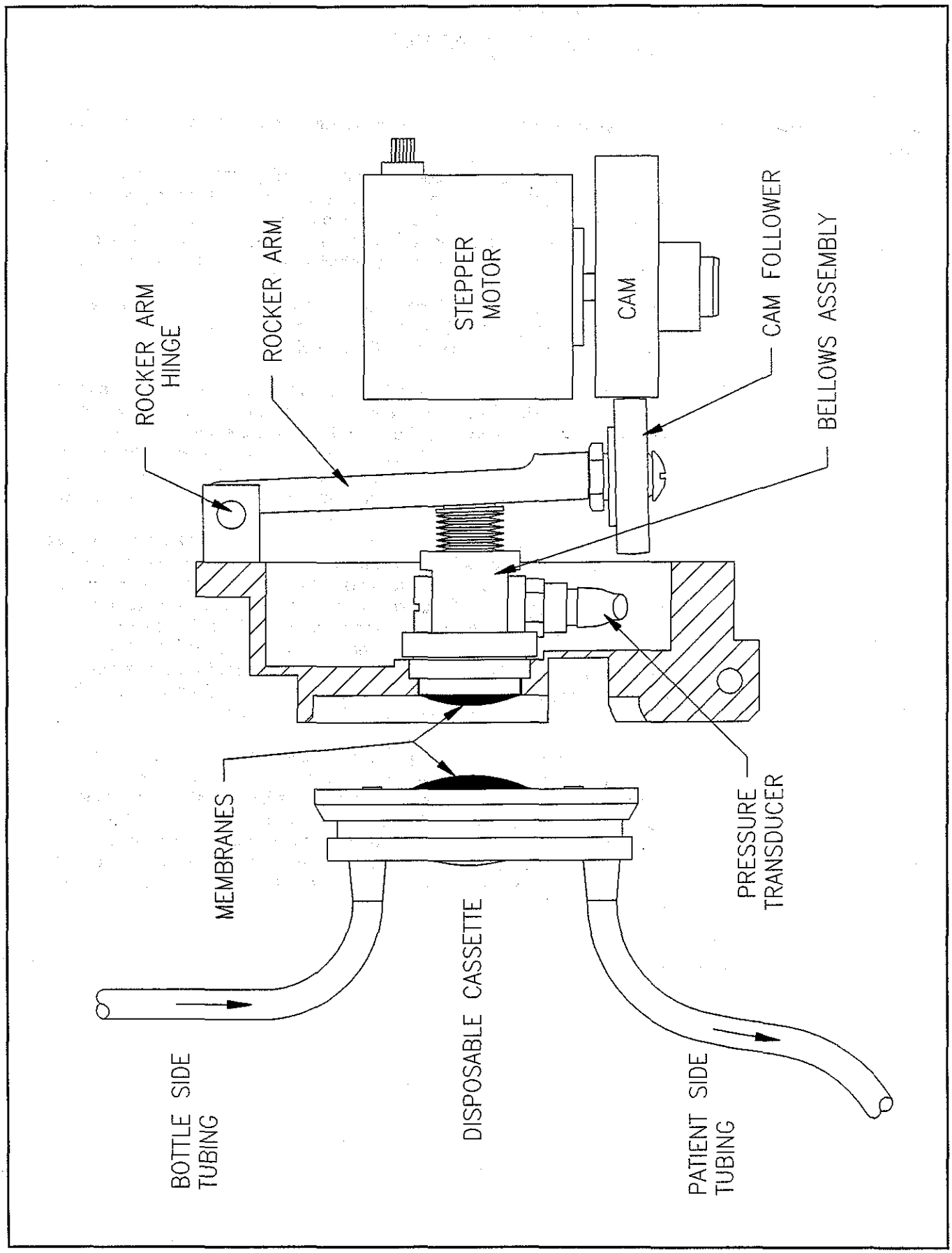
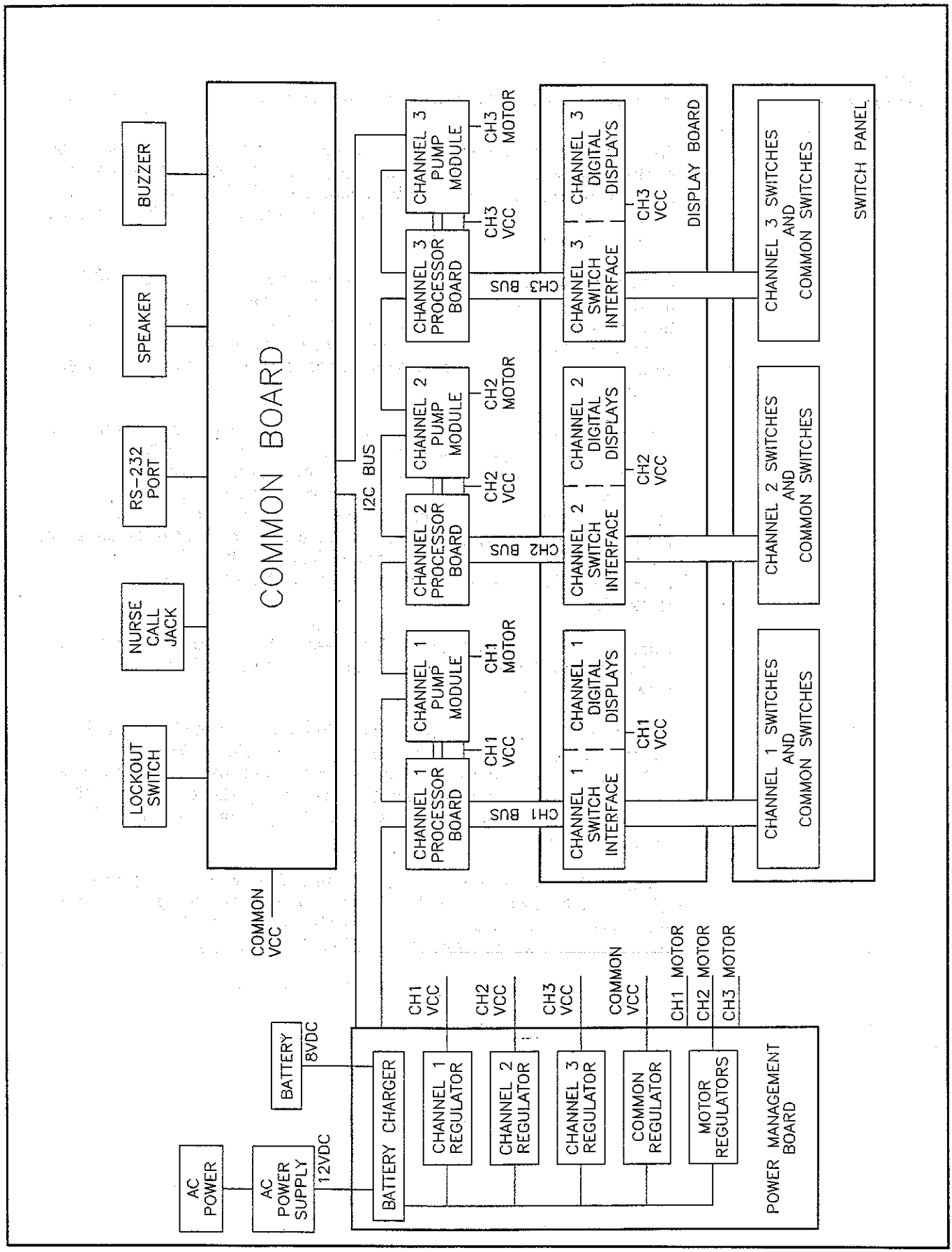


Figure 2. Electronic System Diagram



Refill/Delivery Cycle

Fluid is delivered to the patient using a two part pumping cycle consisting of a refill stroke and a delivery stroke. During the refill stroke, the reservoir in the disposable cassette fills with fluid supplied by the I.V. fluid container and the cassette is pressurized. During the delivery stroke, approximately .2 ml of fluid is infused to the patient.

Each complete pump cycle is a single motor revolution and requires 400 motor steps. The first 120 motor steps occur during the refill stroke which takes approximately .3 seconds to complete. The remaining 280 motor steps occur during the delivery stroke and the stepping rate is altered to correspond to the programmed infusion rate and the volumetric calibration factor.

Attached to the motor is a vane which cuts through two optical sensors, the position sensor and the motion sensor. The position sensor tells the microprocessor when the refill and delivery cycles are complete and the motion sensor tells the microprocessor if the motor is turning. If the microprocessor does not detect motion or position sensor steps, as determined by the programmed flow rate, the infusion will stop and the audio alert will activate to notify the user of a malfunction. In addition, the SYSTEM CHECK indicator on the control panel for the channel will illuminate.

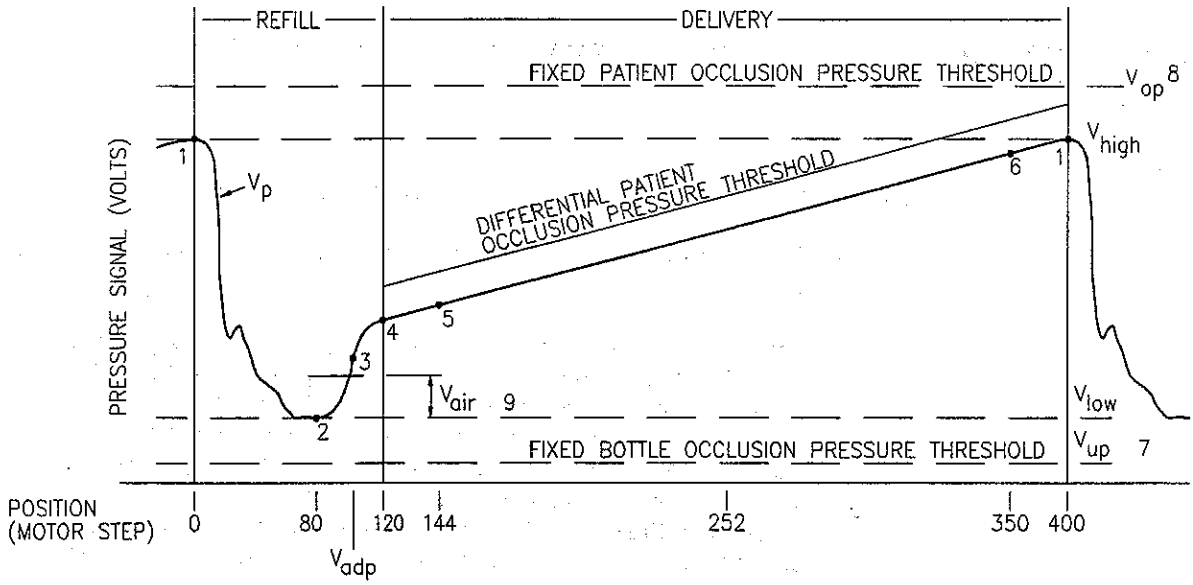
Attached to the bellows assembly is a pressure transducer which is used to generate PATIENT OCCLUSION, BOTTLE OCCLUSION, and AIR IN CASSETTE alerts.

During the refill stroke, if pressure within the bellows assembly falls below a predetermined level, the microprocessor will generate a BOTTLE OCCLUSION alert. During the delivery stroke, if pressure within the bellows assembly exceeds the pressure set by the user adjustable pressure limit or the fixed pressure limit, the microprocessor will generate a PATIENT OCCLUSION alert.

To determine if air is in the cassette, the microprocessor will monitor the rate of pressure increase in the bellows assembly at the end of the refill stroke. If the rate of increase is less than a predetermined value, the microprocessor will generate an AIR IN CASSETTE alert.

Figure 3 shows the typical pressures observed during one pumping cycle.

Figure 3. Bellows Pressure Curve



Events:

1. V_{high}: Highest pressure reached during cycle. End of delivery, start of refill. (step 1)
2. V_{low}: Lowest pressure reached (occurs approximately at step 70-90)
3. V_{adp}: AIR IN CASSETTE detect point (occurs approximately at step 107-125)
4. Beginning of fluid delivery (patient valve opens, approximately step 120)
5. $V_{ref}L$: Lower slope detection point for differential occlusion pressure
6. $V_{ref}H$: Higher slope detection point for differential occlusion pressure

Thresholds:

7. V_{up}: The fixed BOTTLE OCCLUSION pressure threshold
8. V_{op} : The fixed PATIENT OCCLUSION pressure threshold
9. V_{air}: Air detect offset voltage

Patient Occlusion Detection

(Refer to Figure 3)

There are two patient occlusion detection modes in the Trilogy:

1. Fixed occlusion pressure alert. This occlusion limit is between 10 and 15 PSI.

2. *Differential occlusion pressure alert. This is a variable pressure* occlusion alert dependent upon the initial pressure in the patient line during the first complete pumping cycle and the pressure limit selected by the user. The user may select either a HIGH, MEDIUM, or LOW occlusion pressure limit, which corresponds to approximately 8, 4, or 2 PSI occlusion limit above the initial pressure in the patient line. However, this occlusion limit can not exceed the fixed occlusion pressure limit, regardless of the initial pressure.

   The differential occlusion pressure alert can be disabled in the Biomed mode, selection #7, Set Max Pressure. When this is disabled, the occlusion alert will be the fixed occlusion pressure alert.

The fixed PATIENT OCCLUSION alert occurs when the pressure inside the bellows generates the following condition:

$V_p > V_{op}$; where : V_p is the voltage from the bellows transducer

V_{op} is the fixed occlusion constant. This is calculated during calibration in Biomed mode, selection #2, Pressure Cal.

The differential PATIENT OCCLUSION alert occurs when the pressure inside the bellows generates the following condition:

$V_p > V_{ip} + V_{limit}$; where: V_p is the voltage from the bellows transducer

V_{ip} is the initial voltage from the bellows transducer, at the corresponding motor step, during the first complete pumping cycle,

V_{limit} is 0.15, 0.30, or 0.60 VDC which corresponds to approximately 2, 4, or 8 PSI.

To determine V_{ip}, the microprocessor will sample two points on the V_p curve during the delivery stroke of the first complete pumping cycle. The points sampled are $V_{ref}L$ and $V_{ref}H$. These points will be used to *calculate the slope of* V_p *during the initial delivery cycle which the* microprocessor will use to continuously calculate V_{ip} at each motor step.

2.4

Bottle Occlusion Detection

(Refer to Figure 3)

The BOTTLE OCCLUSION alert limit is between -8" and -13" Hg.

The BOTTLE OCCLUSION alert occurs when the pressure inside the bellows generates the following condition:

$V_p < V_{up}$; where: V_p is the voltage from the bellows transducer

V_{up} is the occlusion constant. This is calculated during calibration in the Biomed mode, selection #2, Pressure Cal

2.5

Air In Cassette Detection

(Refer to figure 3)

The air detect limit is between 20 and 100 micro-liters of air trapped in the cassette.

During the refill stroke, an AIR IN CASSETTE alert occurs when the pressure inside the bellows generates the following condition:

$V_{adp} < (V_{low} + V_{air})$; where: V_{adp} is the voltage from the bellows transducer at the Air Detect Point. The Air Detect Point is determined during calibration in the Biomed mode, selection #3, Air Detect Cal.

V_{low} is the lowest voltage detected from the bellows transducer during the current refill stroke

V_{air} is 0.25 VDC

Microprocessor Board(s)

There are three microprocessor boards in the Trilogy. Each board controls one pumping channel and the three boards work in parallel to control the common functions. All three operate identically and communicate with each other via an I^2C bus, which is a serial communication bus.

FUNCTIONAL LEVEL

The Microprocessor Boards:

- Read the control panel switches and adjust the operating parameters accordingly. The switches include those used to control the common functions of the pump, the cassette door switch, and the lockout switch.
- Control the digital displays and alert status indicators on the front panel.
- Control the FLOW RATE, VOLUME TO BE INFUSED counter, and TOTAL INFUSED counter.
- Assure that the speed of the motor is correct for the programmed flow rate.
- Monitor the bellows pressure transducer voltage to generate PATIENT OCCLUSION, BOTTLE OCCLUSION, and AIR IN CASSETTE alerts.
- Monitor the battery charge counter, battery voltage, and battery current, which is used to generate battery status alerts and battery operating time messages.
- Control the audio alert, the buzzer, and nurse call relay.
- Format data for the RS-232 port.
- Store the operating parameters of the pumping channel in the battery backed-up RAM located on the Common Board.

SCHEMATIC LEVEL (Refer to Microprocessor Board Schematic in Section 7)

U4 is the microprocessor, **U2** is the ROM, and **U1** is the RAM. **U3** is used to demultiplex the lower address bits, **A0 - A7**, from the address/data bus, **AD0 - AD7**. **U5** decodes the address bus, **A8 - A15**, to generate enable signals for the ROM, the RAM, the display I/O port, output port 1, output port 2, input port 1, and the I^2C controller.

U11 is the display I/O port and interfaces the control panel switches and displays to the microprocessors via the address/data **AD0 - AD7**. The display address/data bus, **CHnAD0 - CHnAD7**, is routed to the Display Board where the interface with the switches and displays is located.

U7 is output port 1 and generates the following control signals:

WD2PET - This continuously resets watchdog timer #2, **U8**. If the watchdog timer does not see **WD2PET** change state at least every 100 msec (1.2 seconds for the first change after power up), it will time out and reset the microprocessor and output ports 1 & 2. This in turn causes the Power Management Board to activate the buzzer, illuminate the CHANNEL SYSTEM CHECK indicator, and turn off power to the channel.

BUZZ - This is routed to the buzzer via driver **Q1** and activates the buzzer.

BINGBONG - This is routed to the Common Board via driver **Q5** and activates the audio alert.

NURSE - This is routed to the Common Board via driver **Q2** and activates the nurse call relay.

CHnRESET* - This notifies the Power Management Board that the channel has turned off. If the channel is turned off by the POWER switch on the control panel, the microprocessor notifies the Power Management Board via the I^2C bus that it is turning off the channel and **CHnRESET*** is used by the Power Management Board to turn off power to the channel. However, if a power failure or a watchdog time out occurs, **CHnRESET*** will cause the Power Management Board to activate the audio alert, illuminate the CHANNEL SYSTEM CHECK indicator, and turn off power to the channel.

I2CSEL - This enables the two switches for the I^2C bus, **Q9** and **Q8**.

PMEEPA1 & **PMEEPA2** - These address the EEPROM on the Pump Module Interface Board. The calibration factors for the BOTTLE OCCLUSION alert, PATIENT OCCLUSION alert, AIR IN CASSETTE alert, and volumetric accuracy are stored in the EEPROM. The microprocessor writes to the EEPROM, via the I^2C bus, when the unit is calibrated in the Biomed mode, and reads from the EEPROM, via the I^2C bus, during operating modes.

U15 is output port #2 and generates the following control signals:

SYSCHK - This illuminates the CHANNEL SYSTEM CHECK indicator via driver **U14D**.

LOCK - This illuminates the LOCK indicator via driver **U14F**.

DPORT - This illuminates the DATA PORT indicator via driver **U14C**.

LOBAT - This illuminates the LOW BAT indicator via driver **U14E**.

COMMON - This illuminates the COMMON SYSTEM CHECK indicator via driver **U14G**.

WD1PET - This continuously resets watchdog timer #1, **U12**. If the watchdog timer does not see **WD1PET** change state at least every 100 msec (1.2 seconds for the first change after power up), it will time out and reset the microprocessor and output ports 1 & 2. This in turn causes the Power Management Board to activate the buzzer, illuminate the CHANNEL SYSTEM CHECK indicator, and turn off power to the channel.

U9 is input port 1 and allows the microprocessor to monitor the status of the common alert indicators, the position of the pumping motor, the status of the cassette door, and the RS-232 handshaking input. The signals which are monitored are :

COMMON* - This is the cathode of the COMMON SYSTEM CHECK indicator and it notifies the microprocessor when a common system check is called by any of the microprocessors.

LOCK* - This is the cathode of the LOCK indicator and it notifies the microprocessor that the front panel lockout mode is active. Any of the three microprocessors may illuminate the LOCK indicator. When this mode is active, the microprocessor will not respond to any changes made to the control panel switches.

LOBAT* - This is the cathode of the LOW BAT indicator and it notifies the microprocessor that the battery has entered the low or depleted battery state. Any of the three microprocessor boards may illuminate the LOW BAT indicator.

CHnSYCHK* - This is the cathode of the CHANNEL SYSTEM CHECK indicator. The Microprocessor Boards or the Power Management Board can illuminate these three indicators.

HSKI - This is from the RS-232 communication interface located on the Common Board and notifies the microprocessor of the status of the communication port handshaking input line.

CHnCLSW* & **CNLSW*** - These are the normally open and normally closed terminals of the door switch located on the Pump Module Interface Board. These are used by the microprocessor to generate the *INSERT CASSETTE AND CLOSE DOOR* and the *DOOR OPEN* messages whenever the cassette door is open or the cassette door is closed without a cassette in place.

POSSENSE - This is the output from the position sensor on the Pump Module Interface Board. This sensor is activated by the outer edge of the vane which is attached to the motor cam. The falling edge of this signal is used, along with the pressure calibration, to notify the microprocessor to start the refill cycle.

U6 is the I^2C bus controller. The I^2C bus is the communication link between the channels and the common electronics. **U6** formats data from the data bus into a serial format, generating two signals **SDAT**, serial data, and **SCLK**, serial clock. These two signals drive the I^2C bus when switches **Q9** and **Q8** are activated by **I2CSEL**.

U12 and **U8** are redundant watchdog timers and are continuously reset by a state change of the signals **WD1PET** and **WD2PET**. If either timer is not reset at least every 100 msec (1.2 seconds for the first state change after power up), the timer will time out and reset the microprocessor and output ports 1 & 2. This in turn will cause the Power Management Board to activate the buzzer, illuminate the CHANNEL SYSTEM CHECK indicator, and turn off power to the channel.

Crystal **Y2** generates a 6 MHz clock which is divided down to a 3 MHz clock and a 1.5 MHz clock by **U16A** and **U16B**.

The 3 MHz clock is used to clock **U6**, the I^2C controller. Bus access on the shared I^2C bus is controlled by the channel time slot clock **CHnTS**, which is generated on the Common Board and connected to input pin 18 on the microprocessor.

The 1.5 MHz clock is routed to an input port, pin 32 of the microprocessor, **U4**. The software will compare this frequency to a derivative of the main clock generated by crystal **Y1**. If a difference exists, a CHANNEL SYSTEM CHECK will be initiated.

MOTSENSE, the motor motion sensor on the Pump Module Interface Board, is an input to the microprocessor at pin 17. **MOTSENSE** is triggered by the many slots on the vane attached to the motor cam. The microprocessor uses **MOTSENSE** to verify that the motor is moving at the proper speed. If it is not, a CHANNEL SYSTEM CHECK will be initiated.

There are four A/D conversion inputs on the microprocessor. These are used for the following analog signals:

PRESS - This the output of the bellows pressure transducer amplifier, which is located on the Pump Module Interface Board. The microprocessor uses this signal to generate the PATIENT OCCLUSION, BOTTLE OCCLUSION, and AIR IN CASSETTE alerts. In addition, the relationship between the motor position, **POSSENSE**, and the maximum pressure is checked. A CHANNEL SYSTEM CHECK alert is initiated if there is a discrepancy.

2.5V - This is a precise voltage controlled by **VR1**. It is used by the microprocessor to calibrate the A/D conversion for measurement of battery voltage and battery current. If there is a discrepancy a CHANNEL SYSTEM CHECK is initiated.

CHnIBAT is the signal **IBAT** after it passes through switch **Q6**. **IBAT** is a measurement of the current in the battery circuit which the microprocessor uses, in conjunction with **VBAT**, to generate LOW BATTERY and DEPLETED BATTERY alerts. **IBAT** is generated on the Power Management Board.

CHnVBAT is the signal **VBAT** after it passes through switch **Q7**. **VBAT** is a measurement of the battery voltage which the microprocessor uses, in conjunction with **IBAT**, to generate LOW BATTERY and DEPLETED BATTERY alerts. **VBAT** is generated on the Power Management Board.

The bipolar stepper motor is controlled indirectly by outputs from the microprocessor. The control signals are **MDPHA**, **MDIA1**, **MDPHB**, **MDIB1**, and **MD2PHON***. These signals are routed to the motor drivers located on the Pump Module Interface Board. In addition, the **PWM** output, pin 28 of the microprocessor, is integrated by **U18B** generating the **MTRI** voltage which is used to control the current to the motor. The duty cycle of the **PWM** output is controlled by software; the **MTRI** voltage is proportional to the duty cycle and is increased as the motor advances through the pumping cycle, thus increasing the torque of the motor as pressure within the bellows increases.

The transmit data line for the RS-232 data port is **CHnTXD**, pin 16 on **U4**, and the receive data line is **RXD**, pin 15 on **U4**.

2.7

Display Board

The Display Board contains three user interfaces, one for each of the three pumping channels, as well as a common user interface. Each of the three channel displays operate independently and contain no common electronics.

FUNCTIONAL LEVEL

The Display Board:

- Interfaces the control panel switches to each of the three Microprocessor Boards. The channel switches are routed only to their corresponding Microprocessor Board whereas the common switches are routed to all the Microprocessor Boards.

- Demultiplexes and drives the digital displays, alphanumeric displays, and alert status indicators for each channel.

- Contains the common alert status indicators.

SCHEMATIC LEVEL (Refer to Display Board Schematic in Section 7)

The three interfaces operate nearly identically and only channel 1 will be described. Page 1 of the schematic is for channel 1, page 2 for channel 2 and page 3 for channel 3.

U102 is used to demultiplex the address bus, **CH1A0 - CH1A7**, from the channel 1 address/data bus, **CH1AD0 - CH1AD7**. **U104** decodes the upper portion of the address bus, **CH1A3 - CH1A7**, to generate enable signals for the input/output ports.

U109 is enabled by **COMKEY1*** and is the input port for the common switches, CHKBAT, DISPLAY, ADJUST, SELECT, and QUIET, and the POWER switch, **CH1PWRSW***. These switches are located on the Control Panel and connected to the Display Board via connector **J1A**. The switches are held at a high logic level by resistors **RP2A - RP2E** and pulled to a low logic level when activated. **CH1PWRSW*** is also routed to the Power Management Board where it is used to turn on channel 1.

U107 is enabled by **SCAN1*** and is the input port for channel 1 control switches. The control switches are configured in a matrix consisting of three rows and six columns. The rows are addressed by **ROW10**, **ROW11** and **ROW12** and the columns are scanned by **U107**. **U110A - U110C** generate **ROW10**, **ROW11**, and **ROW12** from the lower bits of the address bus, **CH1A0 - CH1A2**. The columns are **COL10 - COL15** and are connected to pins 2 through 7 of **U107**. Reference the Control Panel Schematic in Section 7 for switch locations within the matrix.

U105 is the output port for the FLOW RATE display, the VOLUME TO BE INFUSED display, and the ALERT STATUS indicators. **CLK1*** enables the port. The output of the port is connected, via source driver **U103** and series resistors, to the anode segments of each of the digits, **DS101 - DS108**, and the anodes of the ALERT STATUS indicators, **E101 - E109**. Each of the digits and the bank

of ALERT STATUS indicators are enabled, one at a time, by **CA10 - CA20**. **U106** generates **CA10 - CA20** from the lower bits of the address bus, **CH1A0 - CH1A3**, and the enable signal **CLK1**. These signals are driven by **U108** and **U101** which sink the common cathodes of each of the digits and the group of alert indicators.

DS109 and **DS110** are the alphanumeric displays for the TOTAL INFUSED display. These are enabled by **ALPHA1*** and the segments are addressed by the lower bits of the address bus, **CH1A0 - CH1A3**.

The CH1 SYSTEM CHECK indicator is **E110** and is controlled by **CH1SYSCHK***, which is generated on the channel 1 Microprocessor Board and the Power Management Board.

The common alert status indicators are **E1 - E7** and are controlled by signals generated on various boards.

LINE*, **CHARGE**, and **BAT*** are generated on the Power Management Board.

COMMON*, **LOBAT***, **LOCK***, and **DPORT*** are generated on the three Microprocessor Boards.

Pump Module Interface Board(s)

There are three Pump Module Interface Boards in the Trilogy. Each of these operate independently and contain no common functions.

FUNCTIONAL LEVEL

The Pump Module Interface Boards:

- Amplify and scale the output of the bellows pressure transducer.
- Contain the optical sensors for motor position and motor motion.
- Contain the EEPROM which stores the calibration parameters for the pumping module.
- Drive the stepper motors.
- Contain the cassette door switch which is used to notify the microprocessor if a cassette is installed in the channel.

SCHEMATIC LEVEL (Refer to the Pump Module Interface Schematic in Section 7)

U5A provides the excitation current for the bellows pressure transducer. **U6A - U6C** amplifies the output of the transducer and **U6D** provides the 1.0 volt offset for the transducer amplifier. The amplifier has a gain of 76 millivolts/PSI and an offset such that 0 PSI = 1.0 volts. The output signal, **PRESS**, is used by the Microprocessor Board to generate the PATIENT OCCLUSION, BOTTLE OCCLUSION, and AIR IN CASSETTE alerts.

U8 is the motor motion sensor and is activated by the slots in the vane attached to the motor cam. **U9A** conditions the output of the sensor, resulting in the signal **MOTSENSE**. **U7** is the motor position sensor and is activated by the the outer edge of the vane attached to the cam of the motor. **U9B** conditions the output of the sensor, resulting in the signal **POSSENSE**. The Microprocessor Board uses **MOTSENSE** and **POSSENSE** to verify that the motor is running at the proper speed in accordance with the programmed rate and to determine the position of the motor. If an error is detected, the microprocessor initiates a CHANNEL SYSTEM CHECK alert.

U2 is an EEPROM interfaced to the I^2C bus. The signals **PMSDA** and **PMSCL** are routed from the Microprocessor Board and are isolated from the signals **COMSDA** and **COMSCL** when the Microprocessor Board is not accessing the I^2C bus. These transfer information from the Microprocessor Board to the EEPROM, **U2**, which is addressed by **PMEEPA1** and **PMEEPA2**. These two address signals are generated on the Microprocessor Board. The calibration constants for the PATIENT OCCLUSION alert, BOTTLE OCCLUSION alert, AIR IN CASSETTE alert, and volumetric accuracy are stored in this location.

U1 and **U4** drive the two coils of the bipolar stepper motor. One coil is controlled by signals **MDPHA**, **MDIA1**, and **MD2PHON***. The other coil is controlled by the signals **MDPHB**, **MDIB1**, and **MD2PHON***. **U3** produces **MDIA0** and **MDIB0** which are used to reduce the coil current to 60% when both coils are driven. The current for both coils is controlled by the **MTRI** voltage. The other motor control signals are direct outputs of the microprocessor.

SW1 is the cassette door switch and is activated when a cassette is inserted in the door and the door is closed. The resulting signals, **CNLSW*** and **CLSW***, are used by the Microprocessor Board to generate the *INSERT CASSETTE AND CLOSE DOOR* message. The **CLSW*** signal is also used by the Power Management Board to quiet the buzzer if a power fail or watchdog time out CHANNEL SYSTEM CHECK occurs. (Under these conditions, pressing the POWER key will reset the alarm and power up the channel. However, if the problem recurs, the only way to quiet the buzzer is to open the cassette door.)

Common Board

The Common Board contains functions shared by the three channels. Each of the three Microprocessor Boards can control these functions.

FUNCTIONAL LEVEL

The Common Board:

- Generates the Bing-Bong and the depleted battery audio alerts.
- Adjusts the volume of the audio alert.
- Activates the back-up buzzer if there is an open circuit fault in the speaker circuit or a failure of the audio alert circuit.
- Contains the nurse call relay.
- Contains the RS-232 interface.
- Interfaces the lockout switch.
- Contains the battery backed-up memory used to store the alert volume level, the rate mode, the pressure setting, and each of the channels' operating parameters.
- Generates signals to control access to the I^2C bus.
- Regulates the buzzer supply voltage.

SCHEMATIC LEVEL (Refer to the Common Board Schematic in Section 7)

U11 is the clock for the audio alert which is divided by **U7** to a frequency of 17.2 kHz. **U8** divides the frequency by a factor of 4, 9, or 12 depending upon its preload conditions which are controlled by **U12**.

U14B generates a 10 millisecond **PULSE** output once every second. When **BINGBONG*** is low: if **TONE** is high, **U12** produces the controls for the BingBong sound; if **TONE** is low, **U12** produces the controls for the Beep sound. (The Beep sound is used for the depleted battery alert.) **U12** sets the **PLUCK*** output low for the 10 milliseconds **PULSE** period at the beginning of the Bing, the Bong and the Beep; this turns on **Q5** to charge **C11**. When **PLUCK*** returns high, **Q5** turns off, and **C11** discharges generating the exponentially decayed envelope. For the BingBong sound, **U12** alternates the **D1**, **D4**, and **D8** outputs during the two tones for divide by 9 and divide by 12, and sets the **FILTER** output high. For the Beep sound, **U12** sets the **D1**,**D4**, and **D8** outputs for divide by 4, and sets the **FILTER** output low. When **BINGBONG*** is low, **U12** sets its **OSC** output high during the Bing, two seconds of Bong, and continuously during the Beep, and is low during the last three silent seconds after the Bong sound.

The **TONE** signal is controlled via the I^2C bus through U1.

The output of **U8** is turned into a square wave by **U5A**. **U9A**, **U9B**, and **U2** control the amplitude of the audio alert frequency.

U9A provides an exponential decay envelope for the tone signals and **U2** controls the volume of the audio alert by acting as a resistive voltage divider. **U2** is an analog switch and will connect one of seven resistors to pin 5 of **U9B**, which in turn controls the volume of the audio alert. The signals **VOLADJ1**, **VOLADJ2**, and **VOLADJ3** control **U2**, and are controlled via the I^2C bus through **U1**.

U9C filters and buffers the alarm signal and **U10** is the final amplifier.

VR1 is a -5 VDC regulator that supplies the negative rail for the audio amplifier to allow the amplifier output to pull completely to ground.

U13A monitors the current in the speaker circuit and triggers **U13B** if the current is too low. This in turn generates **BUZZER*** which turns on the back-up buzzer.

U6 is the **RS-232** interface. Information is transmitted from **CH1TXD**, **CH2TXD**, and **CH3TXD** which are generated on the three Microprocessor Boards. **XMIT1***, **XMIT2***, and **XMIT3*** select which channel is transmitted. These signals are controlled via the I^2C bus by **U1**. **RXD** is the data received and is routed to all three microprocessors. The outputs of **U6**, **RS232TXD** and **RS232HSKO**, and the inputs to **U6**, **RS232RXD** and **RS232HSKI**, are routed to the **RS-232** connector on the rear of the pump.

The timing signals **CH1TS**, **CH2TS**, and **CH3TS** are used to control when each microprocessor can access the I^2C bus. There are two versions of the clock source for **CH1TS**, **CH2TS**, and **CH3TS**. The earlier version used **U15** to generate a 8 Hz clock. The later version uses a 7.63 Hz frequency from **U11**. In both versions the clock is divided by **U16A** and **U16B** and routed through **U17** to create **CH1TS**, **CH2TS**, and **CH3TS**. These signals are routed to the appropriate Microprocessor Board.

U14A is used to debounce the lockout switch. Its output is monitored by the microprocessors through I^2C port, **U1**. The debounce circuit provides the time required for all three microprocessors to sense lockout switch activations.

U4 is a memory IC and clock calendar, which is backed-up by battery **BT1**, and is used to store the audio alert level, the rate mode, the pressure setting, and the operating parameters for each channel. This includes the FLOW RATE, VOLUME TO BE INFUSED, and the TOTAL INFUSED.

K1 is the nurse call relay and electrically connects **NURSE1** and **NURSE2**, the two signals from the nurse call jack located on the back of the pump. **NURSE*** activates the relay and is generated on the three Microprocessor Boards and the Power Management Board. **NURSE*** is active whenever the audio alert is active except during the power up audio alert check.

VR2 is a voltage regulator that limits the buzzer voltage to 6.2 volts.

Power Management Board

The Power Management Board generates the regulated voltages for the other boards, charges the battery, and controls the power on/off circuits.

FUNCTIONAL LEVEL

The Power Management Board:

- Generates independent +5.0 power sources for each of the three Microprocessor Boards and the Common board.
- Generates +12.0 volt current limited power sources for each of the three pumping motors.
- Charges the battery.
- Provides indications of battery voltage, current, and charge for calculating battery operation time.
- Turns the three channels on/off.
- Monitors the three Microprocessor Boards for watchdog timer reset and generates appropriate SYSTEM CHECK alerts.
- Drives the BAT, CHARGE, and LINE indicators on the Display Board.

SCHEMATIC LEVEL (Refer to the Power Management Board Schematic in Section 7)

The 12 volt output of the main power supply or the output of the battery are used to generate the following supplies:

- Standby +5.0 VDC, **+5V(STBY)**, which is always active and is used to power the control PLD, the battery charge counter, and the power fail one-shots. **VR9** generates this supply.
- Common +5.0 VDC, **VCC**, generated by **VR6** is activated by **MAINPWR***. **MAINPWR*** is an output of **U8**, the control PLD for this board, and is active whenever the pump is connected to AC power or a channel is operating. **VCC** is used by the Common Board, the Power Management Board, and by **VR8** to generate +15.0 VDC and -5.0 VDC for the Power Management Board analog circuits.

The 12 volt output of the main power supply and the output of the battery are also switched through **Q10**, which is controlled through **U9**, generating **VUNREG** which is routed to the various voltage converters. **U9** is controlled by the signal **MAINPWR*** which is an output of **U8**, the control PLD for the board. The following voltages are generated from **VUNREG**:

- Channel 1 +5.0 VDC, **CH1VCC**, generated by **VR4** is activated by **CH1PWR***. **CH1PWR*** is an output of **U8** and is active when channel 1 is operating.

- Channel 2 +5.0 VDC, **CH2VCC**, generated by **VR3** is activated by **CH2PWR***. **CH2PWR*** is an output of **U8** and active when channel 2 is operating.

- Channel 3 +5.0 VDC, **CH3VCC**, generated by **VR1** is activated by **CH3PWR***. **CH3PWR*** is an output from **U8** and is active whenever channel 3 is operating.

- Motor voltage, **VMTR**, the output of **VR5**, is a 12 VDC supply and is used to generate the voltage for the motors. The output of **Q4**, **CH1VMTR**, limits the current to channel 1 motor, the output of **Q8**, **CH2VMTR**, limits the current to channel 2 motor, and the output of **Q9**, **CH3VMTR**, limits the current to channel 3 motor.

Q5 is the pass transistor for the battery charge circuit. **Q5** is controlled by **U5** which is a lead acid battery charger IC configured as a dual level float charger.

The battery is charged at a constant current with a nominal limit of approximately 1.0 A (0.40 A on earlier versions) and a nominal voltage limit of 9.9 V. When the battery approaches full charge, the charger enters a 9.4 V float charge state.

The battery charger **U5** outputs status signals which are used to inform the control PLD, **U8**, of the battery status:

- **PI*** is active when the power input to the charger exceeds approximately 4.5 VDC.

- **OCI*** is active when the charger enters the over-charge indicator state.

- **FLOAT*** is active when the charger has entered the float charge state.

U6A and **U6B** amplify the signal **BATTERY-**, the voltage across **R55** in the battery circuit, which is proportional to the battery current. **U3** converts the output voltage of **U6B, IBAT,** to a frequency. The output of **U3** is 14913 Hz per amp of charge current and 18641 Hz per amp of discharge current. The output frequency of **U3** is divided by **U2**, a 2^{23} counter. During discharge **U2** outputs a pulse for each 0.125 amp-hour and during charge one pulse for each 0.156 amp-hour. **U8** counts the pulses from **U2** in a five bit counter. The output of this counter, **CHG0 - CHG4**, is accessed by the Microprocessor Boards via the I^2C bus through **U7**. The Microprocessor Boards use this information to determine the charge remaining in the battery.

U6D is used as a comparator which compares the forward voltage of **D2** with the forward voltage of **D7**. The forward voltage of both of these diodes is a function of the current flowing through the diodes. The current in **D7** is nearly constant, dependent upon the charger output voltage (the battery voltage plus **D2** forward (voltage), and the resistance of **R23**. The current in **D2** is the battery charge current plus the current flowing in the charger voltage sense divider (**R40**, **R15**, **R14** and **R16**). **R23** is selected so that the comparator output is on when the battery charge current exceeds

approximately 1.5 mA. The output of **U6D** drives a peak detector comprised of **D4**, **C12** and **R48**. The peak detector output controls **Q11**, which controls the CHARGE indicator on the control panel, and provides an indication to the software, through the I^2C port, **U7**, that the battery is accepting a charge.

When the battery is fully charged and the charger circuit is in float charge state, the battery current from the charger may drop to less than 1.5 mA. The CHARGE indicator would turn off, and the software would sense that the battery is not charging and signal this event with an alarm. To prevent this, the circuit comprised of **Q2**, **Q3**, **R42** (and **C8**, **R38**, **R39** and **R41**) provides current pulses to the battery. The amplitude of these pulses is a function of the 12V power supply voltage, the battery voltage, the voltage drops across **D2** and **Q3** (when turned on), and the resistance of **R42**. Under normal full charge conditions, the amplitude of this current pulse is about 2 mA, sufficient to turn on comparator **U6D**. The duration of the pulses is controlled by the time constant of **C8** and **R38**, and is nominally about 1.4 ms. The pulse frequency is about 8 Hz, and is generated by the common board TSCLK signal.

If the battery circuit is opened, and comparator **U6D** turns off, transistor **Q11** will remain on for a time determined by the time constant of **R48** and **C12**. Typically, the CHARGE indicator on the control panel will turn off about 2 seconds after the battery circuit is opened. The software will indicate this state approximately two minutes after the battery circuit is opened.

U8 monitors the signals from the battery charger, **PI***, **OCI***, **FLOAT***, and **CHARGE**. When **PI***, **FLOAT***, and **CHARGE** are active and **OCI*** is inactive **U8** will enable the signal **FULL** which applies approximately 4 volts to the input of **U3** and significantly increases the output frequency of **U3**, which in turn forces the counter in **U8** to reach its maximum count of 31. This informs the microprocessors that the battery is at full charge.

U8 monitors the power switches **CH1PWRSW***, **CH2PWRSW***, and **CH3PWRSW***. When a power switch is pressed, **U8** enables the signal **MAINPWR***, which turns on the common power, **VCC**, and either **CH1PWR***, **CH2PWR***, or **CH3PWR***, which turns on the power for the appropriate channel.

U8 monitors **CH1RESET***, **CH2RESET***, and **CH3RESET*** which switch to a logic low whenever the corresponding channel turns off. If the power switch is pressed to turn the channel off, the Microprocessor Board sends a signal on the I^2C bus which is decoded by **U7** and causes **NOALRM** to pulse. The pulse on **NOALRM** starts timers **U1A** and **U1B**, generating **PFADIS1** and **PFADIS2***, which are monitored by **U8**. If **CH1RESET***, **CH2RESET*** or **CH3RESET*** are active while **PFADIS1** and **PFADIS2*** are active, **U8** turns off power to the appropriate channel without an alert. If **CH1RESET***, **CH2RESET***, or **CH3RESET*** are active and either **PFADIS1** or **PFADIS2*** is not active, **U8** assumes a power failure or a watchdog time out on the corresponding Microprocessor Board, initiates a CHANNEL SYSTEM CHECK and turns off power to the channel. This is accomplished by activating **BUZZER**, the control signal for the buzzer, NURSE, the control signal for the nurse call relay on the Common Board, and **CH1PFALRM**, **CH2PFALRM**, or **CH3PFALRM** which drive the corresponding CHANNEL SYSTEM CHECK indicator via drivers **Q12**, **Q16**, or **Q17**.

U8 monitors the cassette door switches, **CH1CLSW***, **CH2CLSW***, and **CH3CLSW***, which are used to quiet the buzzer after a CHANNEL SYSTEM CHECK has been initiated by **U8**.

U6C monitors the battery voltage and generates the signal **LOBAT** via driver **Q6.** This is NOT related to the LOW BAT indicator on the Display Board. **LOBAT** is active when the battery voltage drops below 6.0 volts. This signal is used by **U8** to turn off the common power supplies in the event of one or more channel power fail alarms when the pump is operating on battery, so as to prevent fully discharging the battery.

U4A also scales the battery voltage generating **VBAT. VBAT** and **IBAT, U6B**, are used by the Microprocessor Boards to monitor battery conditions during discharge and generate low battery and depleted battery alerts.

U8 uses **PI*** from the battery charger to control, via drivers **Q13** and **Q20**, the BAT and LINE indicators on the Display Board.

2.11

Power Supply Board

The Power Supply Board is a 12 VDC, 40 watt switching power supply. The input power requirements are 100-240 VAC, 47-63 HZ.

2.12

Parent Board

The Parent Board interconnects the circuit boards and the rear case electronics. There are no active components on the board.

2.13

Rear Case Assembly

The Rear Case Assembly contains the Power Supply Board, speaker, buzzer, RS-232 port, lockout switch, nurse call jack, AC receptacle, battery, and battery fuse.

Section 3.0
Maintenance Schedule

Recommended Servicing

It is recommended that the Periodic Maintenance Procedure, section 3.1, be performed once every six months. It will take approximately 20 to 30 minutes to perform this procedure.

In addition, the Bellows Assembly, the main battery, and the RAM battery must be checked at six month intervals as described in sections 3.2, 3.3, and 3.4. These items require periodic replacement and have typical replacement periods ranging from 3 to 5 years dependent upon the use patterns of the Trilogy pump.

Note:

Failure to perform the recommended servicing will result in nuisance BOTTLE OCCLUSION and AIR IN CASSETTE alerts, inaccurate battery operating time messages, and/or COMMON SYSTEM CHECK alerts.

BELLOWS REPLACEMENT
NEED
CLAMP FORCE ~~GUA~~ GAUGE

OP MANUAL

LOW	2 ±2	0-4
MED	4 ±2	2-6
HIGH	8 ±2	6-10

Periodic Maintenance Procedure

Equipment Required:

- Graduated cylinder, 25 ml, .2 ml resolution
- 6 Disposable IV sets (not burette or filter sets) such as: IV1A01, IV1L01, IV1A02, IV1A03, IV1A04, IV1A08
- 1 Disposable IV set with Flow Clip (If Flow Clip sets are used)
- 3 IV solution containers with water free of air
- 3 18 AWG Needles
- Electrical safety analyzer

Setup:

- Clean pump as described in the operation manual.

- Inspect the pump for damage such as cracked housings or torn control panels. Repair damage before proceeding.

- Prime 3 IV sets, attach needles, and verify that all the air is purged from the sets.

- Hang the solution containers approximately 24 inches above the cassette doors.

- Connect the pump to AC power.

Procedure:

Note: Sections 3.1.1 through 3.1.6 must be performed for each channel.

3.1.1 DISPLAY CHECK AND AUDIO ALERT CHECK

Press the POWER key to turn on the channel to be tested. Verify that all segments of the FLOW RATE and VOLUME TO BE INFUSED displays illuminate, that the correct *CHANNEL#* is displayed across the message display, that the ALERT STATUS indicators illuminate, and that the audio alert and the backup buzzer activate.

3.1.2 BOTTLE OCCLUSION/ PATIENT OCCLUSION ALERT SENSITIVITY

1. Press SELECT OPTION and ADJUST OPTION simultaneously. Verify that *ENTER CODE AND PRESS ADJUST* is scrolled across the display.

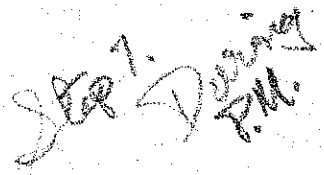
2. Enter access code *663.5* in the FLOW RATE display and press ADJUST OPTION. Verify that *BIOMED MODE - NOT FOR CLINICAL USE* is scrolled across the display.

3. Insert a properly primed cassette into the channel, close the cassette door, and open the roller clamp on the IV set.

4. If *ALL* is not displayed in the VOLUME TO BE INFUSED display, press INFUSE ALL and verify that *ALL* is now displayed

5. Press INFUSE/PAUSE and verify that the pump starts infusing. Allow the pump to operate for approximately 2 minutes and then press INFUSE/PAUSE to stop the pump.

6. Open the cassette door.



7. Press SELECT OPTION as necessary until *2.PRESSURE CAL* is scrolled across the display. Press ADJUST OPTION when *NO* is displayed. Verify that *YES* is then displayed followed by *WAIT*. The unit will then run at 600 ml/hr for approximately 1 minute while the pressures are adjusted. *CAL COMPLETE* will scroll across the display when the calibration is successfully completed. If an error message is displayed, the unit must be repaired. Reference Section 4 and page 1-3 for troubleshooting information.

8. Close the cassette door.

3.1.3 AIR IN CASSETTE SENSITIVITY

1. Verify that a properly primed cassette is inserted into the channel and the cassette door is closed. Verify that the roller clamp on the IV set is open.

   Caution: All the air must be purged from the cassette. Air trapped in the cassette will cause the air detect point to be incorrect or will cause an error message at the end of this calibration.

2. Press SELECT OPTION until *3.AIR DETECT CAL* is scrolled across the display. Press ADJUST OPTION when *NO* is displayed. Verify that *YES* is then displayed followed by *WAIT*. The unit will then run at 745 ml/hr for approximately 30 seconds while the air detect alert is adjusted. *CAL COMPLETE* will scroll across the display when the calibration is successfully completed. If an error message is displayed, the unit must be repaired. Reference Section 4 and page 1-4 for troubleshooting information.

3.1.4 VOLUMETRIC ACCURACY

1. Verify that a properly primed cassette is inserted into the channel and the cassette door is closed. Verify that the roller clamp on the IV set is open.

   Caution: All the air must be purged from the cassette. Air trapped in the cassette will cause the volumetric accuracy to be adjusted incorrectly or will cause an error message at the end of this calibration.

2. Press SELECT OPTION until *4.VOLUMETRIC CAL* is scrolled across the display. Press ADJUST OPTION when *NO* is displayed. Verify that *YES* is then displayed followed by *PRESS INFUSE*.

3. Insert the distal end of the IV set into the graduated cylinder. Press INFUSE/PAUSE. The unit will deliver 20.0 ml of fluid at the rate of 600 ml/hr.

Note: Although this procedure recommends a graduated cylinder to measure fluid volume, other measurement devices may be used, such as electronic balances, pipettes, etc.

4. When the delivery is complete *ENTER MEASURED VOL IN VTBI AND PRESS ADJUST* will scroll across the display. Enter the volume of fluid collected in the graduated cylinder into the VOLUME TO BE INFUSED display and press ADJUST OPTION. *WAIT* will appear in the display while the volumetric calibration constant is determined. *CAL COMPLETE* will scroll across the display when the calibration is successfully completed. If an error message is displayed, the unit must be repaired. Reference Section 4 and page 1-5 for troubleshooting information.

3.1.5 KEYPAD AND LOCKOUT SWITCH CHECK

1. Press SELECT OPTION until *9.KEYPAD CHECK* scrolls across the display. Press ADJUST OPTION when *NO* is displayed. *YES* will appear in the display and then the display will blank.

2. Verify that the LOW BAT, DATA PORT, COMMON SYSTEM CHECK, and CHANNEL SYSTEM CHECK (CH1 or CH2 or CH3) indicators on the front panel illuminate.

3. Press the LOCKOUT switch on the rear of the pump. Verify that the LOCK indicator on the front panel illuminates. Wait at least one second and press the LOCKOUT switch again. Verify that the LOCK indicator is now off. The pump must be out of the lockout mode before proceeding.

4. Press each key, except QUIET ALARM, and verify that a number appears in the display which corresponds with the key as shown in the following table.

00	FLOW RATE TENTHS
01	FLOW RATE UNITS
02	FLOW RATE TENS
03	FLOW RATE HUNDREDS
04	TITRATE DOWN
05	TITRATE UP
06	VTBI TENTHS
07	VTBI UNITS
08	VTBI TENS
09	VTBI HUNDREDS
10	INFUSE ALL
12	TITRATE
13	CLEAR TOTAL
14	INFUSE/PAUSE
18	CHECK BAT
19	DISPLAY
20	ADJUST OPTION
21	SELECT OPTION
23	POWER

6. Press QUIET ALARM and verify that *22* is displayed followed by *BIOMED MODE-NOT FOR CLINICAL USE.*

3.1.6 CASSETTE DOOR SWITCH

1. Open the cassette door latch handle approximately 1 inch from the door. Verify that *INSERT CASSETTE AND CLOSE DOOR* scroll across the display. If this is not displayed, the unit must be repaired. Reference Section 4 for troubleshooting information.

2. Turn off the channel.

Note: Sections 3.1.1 through 3.1.6 must be performed for each channel.

3.1.7 CLEAR ERROR CODES

1. Turn on one channel.

2. Press SELECT OPTION and ADJUST OPTION simultaneously. Verify that *ENTER CODE AND PRESS ADJUST* is scrolled across the display.

3. Enter access code *663.5* in the FLOW RATE display and press ADJUST OPTION. Verify that *BIOMED MODE - NOT FOR CLINICAL USE* is scrolled across the display.

4. Press SELECT OPTION until *1.CHECK/CLEAR ERROR CODES* scrolls across the display.

5. While the COMMON SYSTEM CHECK error codes are displayed or when prompted by a message scrolled across the display, press ADJUST OPTION to clear the error codes.

6. Turn off the channel.

3.1.8 ALERT VOLUME, POWER INDICATORS, AND MEMORY

1. Verify that the pump is connected to AC power. Verify that the CHARGE indicator on the front panel is illuminated.

2. Turn on one of the channels. Verify that the LINE indicator on the front panel illuminates and the BAT indicator is off.

3. Disconnect the pump from AC power. Verify that the BAT indicator on the front panel illuminates and the LINE indicator is off.

4. Program a flow rate using the FLOW RATE keys. Turn off the channel. Turn on the channel and verify the programmed rate appears in the FLOW RATE display. Reconnect AC power.

5. Open the cassette door. Adjust the volume of the audio alert by pressing SELECT OPTION until *ALARM VOLUME* scrolls across the display. Press ADJUST OPTION to increase and decrease the volume of the audio alert. Verify that the volume increases or decreases with each step. Verify that the alert is audible when set to the minimum level. Adjust the volume level to the desired setting.

6. Press QUIET ALARM and verify that the alert is silenced.

7. Turn off the channel.

3.1.9 FLOW RATE AND VOLUME TO BE INFUSED DIGIT VERIFICATION

1. Verify that a primed cassette is installed in each channel.
2. Press the POWER key on each channel and verify that the corresponding channels turn on and go through the powerup sequence. Verify that the software version is the same for all channels.
3. Press each key for the FLOW RATE and VOLUME TO BE INFUSED as necessary to sequence through the full range of digits (blank or 0 through 9) verifying that the keys function and that each digit is displayed.
4. Verify that the decimal point is illuminated on the VOLUME TO BE INFUSED displays and that the decimal point is flashing on the FLOW RATE displays.

3.1.10 TITRATE DIGIT VERIFICATION

1. Press the TITRATE key on each channel and verify that the alphanumeric display alternates between the total infused and *TITRATE*. Press the TENS digit of the FLOW RATE. Verify that the intensity of the tens digit on the FLOW RATE displays is increased.
2. Press the UNITS and TENTHS FLOW RATE keys on each channel and verify that the highlighted digit changes correspondingly.
3. Press the TITRATE key on each channel and verify that *TITRATE* is no longer displayed, and none of the FLOW RATE digits are highlighted.

3.1.11 BOTTLE OCCLUSION ALERT VERIFICATION

1. Set the flow rate to approximately 600 ml/hr for each channel. Set the VOLUME TO BE INFUSED to *ALL* by pressing the INFUSE ALL key on each channel.
2. Press the INFUSE/PAUSE key on each channel to start infusing.
3. Pinch the bottle side tubing on the IV set for each channel and verify that the corresponding channel's fluid delivery stops, the red Alert Status indicators illuminate, *BOTTLE OCCLUSION* is scrolled across the alphanumeric displays, and the audible alarm is activated.
4. Release the tubing on all three channels and press the INFUSE/PAUSE key on each corresponding channel to restart delivery.

3.1.12 PATIENT OCCLUSION ALERT VERIFICATION

1. Pinch the patient side tubing on the IV set for each channel and verify that the corresponding channel's fluid delivery stops, the red Alert Status indicators illuminate, *PATIENT OCCLUSION* is scrolled across the alphanumeric displays, and the audible alarm is activated.

2. Release the tubing on all three channels.

3.1.13 AIR IN CASSETTE ALERT VERIFICATION

1. Remove the primed cassettes from each pump module and install unprimed cassettes in each pump module and close the doors.

2. Press the INFUSE/PAUSE key on each channel and verify that the corresponding channel's delivery starts and then stops, the red Alert Status indicators illuminate, *AIR IN CASSETTE* is scrolled across the alphanumeric displays, and the audible alarm is activated.

3. Remove the unprimed cassette from each channel, close the doors, and press the POWER keys to turn off all channels.

3.1.14 FLOW CLIP CHECK

Note: This check does not need to be performed if the users do not utilize disposable IV sets with Flow Clips.

1. Insert a Flow Clip into Channel 1 cassette door.

2. Open the cassette door and verify that the Flow Clip is released.

3. Close the cassette door.

4. Perform steps 1 through 3 for the other two channels.

3.1.15 AC LINE LEAKAGE

1. Connect the AC power cord of the pump to the safety analyzer. Set the analyzer to normal polarity. Verify a reading of 50 micro-amps or less.

2. Set the analyzer to reverse polarity. Verify a reading of 50 micro-amps or less.

3. Disconnect the power cord from the analyzer.

3.1.16 GROUND CONTINUITY

If the power cord retainer is attached with screws:

1. Connect one lead of the safety analyzer to the ground prong of the AC power connector of the power cord.

2. Set the analyzer to the resistance mode.

3. Touch the other probe to the following points and verify resistance measurements of 200 milli-ohms or less:

   - The nut for the lockout switch
   - The nut for the nurse call jack
   - The two screws securing the RS-232 port
   - Each of the screws securing the three pump modules to the bottom of the pump housing.

4. Disconnect the analyzer..

If the power cord retainer is not attached with screws:

1. Remove the power cord from the pump.

2. Connect one lead of the safety analyzer to the ground prong of the AC power connector of the pump.

3. Set the analyzer to the resistance mode.

4. Touch the other probe to the following points and verify resistance measurements of 100 milli-ohms or less:

   - The nut for the lockout switch
   - The nut for the nurse call jack
   - The two screws securing the RS-232 port
   - Each of the screws securing the three pump modules to the bottom of the pump housing.

5. Disconnect the analyzer and check the continuity of the ground wire in the power cord. Verify that the resistance is less than 100 milli-ohms.

6. Reconnect the pump power cord.

3.1.17 BATTERY CHARGER (Software version 1.3)

Connect the pump to AC power and allow the battery to charge until the message *>3 HRS LEFT* scrolls across the display when the CHECK BAT key is pressed while one channel is turned on.

3.1.18 BATTERY CALIBRATION (Software version 1.5 or higher)

1. Connect the pump to AC power and allow the battery to charge for a minimum of 24 hours.

2. Disconnect the pump from AC power.

3. Operate one or more channels until a Low Battery alert is initiated. (With all three channels pumping at 888.8 ml/hr, it will take approximately 4.5 hours.)

   Caution: Do not turn off any of the channels or apply AC power during the calibration period. Either of these actions will prevent the battery from calibrating.

4. Connect the pump to AC power and allow the battery to charge until the message *>3 HRS LEFT* scrolls across the display when the CHECK BAT key is pressed with one channel turned on.

5.2 3 HOUR BATTERY TEST (Version 1.3 only)

5.2.1 Disconnect the pump from AC power.

5.2.2 Install a primed cassette in each of the three channels and close the doors. Connect an 18 gauge needle to the patient end of the tubing set and insert the needle in the drip chamber access site to allow the fluid to circulate.

5.2.3 Press the POWER keys to turn all 3 channels on. Press the CHECK BAT key and verify that the message *>3 HRS LEFT* is displayed. If not, connect the pump to AC power. Once the battery has reached sufficient charge, disconnect the pump from AC power.

5.2.4 Set the FLOW RATE on each channel to 125.0 ml/hr and press the INFUSE ALL key to set the VOLUME TO BE INFUSED to *ALL* on each channel.

5.2.5 Press the INFUSE/PAUSE key on all 3 channels to start pumping. Record the date, time, and your signature in the 3 Hour Start portion of the Service Test Data Sheet, Attachment I . If an alert is initiated during this period, check the tubing set for a possible cause (i.e. an occluded distal or proximal line, air in the cassette, etc.). If there is an external condition which caused the alert, correct the condition, restart the pump and record the restart date, time, and your signature on the Service Test Data Sheet, Attachment I. If a functional defect interrupts the test, record the defect (including any error codes) in the comments section of the Service Test Data Sheet, Attachment I.

5.2.6 At the end of 3 hours minimum, 3 hours 15 minutes maximum, verify that the pump is still running, and the LOW BAT indicator is not flashing.

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5.2.7 Press the INFUSE/PAUSE key to pause infusion on all 3 channels. Record the date, time, and your signature in the 3 Hour Stop portion of the Service Test Data Sheet, Attachment I, to indicate that pump operation at the end of 3 hours has been verified.

5.3 12 HOUR FUNCTIONAL TEST

5.3.1 Connect the pump to AC power. Install a primed cassette in each channel and connect the patient end of the tubing to an access site above the drip chamber of each tubing set.

5.3.2 Set the FLOW RATE on each channel to 999.9 ml/hr and press the INFUSE/PAUSE key on all 3 channels to start pumping. Record the date, time, and your signature in the 12 Hour Start portion of the Service Test Data Sheet, Attachment I. If an alert is initiated during this period, check the tubing set for a possible cause (i.e. an occluded distal or proximal line, air in the cassette, etc.). If there is an external condition which caused the alert, correct the condition, restart the pump and record the restart date, time, and your signature on the Service Test Data Sheet,

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FULL RELEASE

Attachment I. If a functional defect interrupts the test, record the defect (including any error codes) in the comments section of the Service Test Data Sheet, Attachment I.

5.3.3 At the end of 12 hours minimum verify that the pump is still running.

5.3.4 Press the CHECK BAT key and verify that the message *>3 HRS LEFT* is displayed. If not, continue running until the battery has reached sufficient charge. If the battery has not charged within 24 hours under normal ambient room temperature, the battery or charge circuit may be defective.

5.3.5 Press the INFUSE/PAUSE key to pause infusion on all 3 channels. Record the date, time, and your signature in the 12 Hour Stop portion of the Service Test Data Sheet, Attachment I, to indicate that pump operation at the end of 12 hours has been verified.

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3.2

Bellows Maintenance

The Bellows Assembly has a limited life and will require periodic replacement. The life of this assembly depends upon the usage pattern of the pump and has a typical life of 3 to 5 years.

The indications for replacement are:

1. The inability to calibrate BOTTLE OCCLUSION, PATIENT OCCLUSION, or AIR IN CASSETTE alert sensitivity, or volumetric accuracy.

2. The Bellows Assembly has been in use in excess of 5 years.

The calibration procedures referenced above are located in Section 3.1.

The replacement procedure is located in Section 5.8.

3.3

Main Battery Maintenance

The main battery has a limited life and requires periodic replacement. The life expectancy of the battery depends upon the number and depth of discharges and upon the ambient temperature of the environment in which the pump is used. Examples of expected battery life based upon pump environmental and usage conditions are shown below.

Ambient temperature = 23°C (73°F)

Battery used for emergency power only:	4 years
Daily, 1.5 hours, three channels operating:	3 years
Daily, full discharge to depleted battery shutdown:	6 months

Ambient temperature = 28°C (82°F)

Battery used for emergency power only:	3 years
Daily, 1.5 hours, three channels operating:	2 years
Daily, full discharge to depleted battery shutdown:	4.5 months

Ambient temperature = 33°C (91°F)

Battery used for emergency power only:	2 years
Daily, 1.5 hours, three channels operating:	18 months
Daily, full discharge to depleted battery shutdown:	3 months

Ambient temperature = 40°C (104°F)

Battery used for emergency power only:	18 months
Daily, 1.5 hours, three channels operating:	1 year
Daily, full discharge to depleted battery shutdown:	2 months

Since it is impossible to track environmental and usage patterns of the pump, it is recommended that the battery be replaced in accordance with the following indications:

1. Starting with a fully charged battery, the pump operating time to the onset of low battery alarm with all three channels operating and infusing 125 ml/hr, is less than three hours.

2. The battery has been in use in excess of three years.

3. The message *REPLACE BAT* is displayed when the CHECK BAT key is pressed.

The procedure for battery replacement is located in Section 5.13

3.4 RAM Battery Maintenance

The lithium coin cell is used for maintaining supply voltage to the memory used to store the pump settings, such as alarm sound volume and channel flow rates and infused volume totals, under pump storage conditions. This battery should be replaced every five years, or when there is indication that the pump settings are not retained when the pump is turned off and not connected to AC line power. Note that the pump channel settings are automatically reset 8 hours after a channel is turned off, and that this is not indicative of a depleted RAM battery.

The procedure for the battery replacement is located in Section 5.14.

Section 4.0
Troubleshooting

4.1

Troubleshooting Guide

SYMPTOM	POSSIBLE CAUSES
BOTTLE OCCLUSION Alert	1. Application - Improper venting of fluid container. - Wet vent filter on burette cylinder. - Blue Ball seated in the drip chamber. 2. Calibration - Bottle Occlusion Alert Sensitivity (Section 3.1.2) 3. Bellows Assembly 4. Pump Module Interface Board 5. Microprocessor Board
PATIENT OCCLUSION Alert	1. Application - Infusing viscous fluids at high flow rates through small diameter tubing, catheters, or needles. - Occlusion in filter located between the pump and the patient. - Occlusion in patient catheter. - Pressure limit set too low. 2. Calibration - Patient Occlusion Alert Sensitivity (Section 3.1.2) 3. Bellows Assembly 4. Pump Module Interface Board 5. Microprocessor Board

SYMPTOM	POSSIBLE CAUSES
AIR IN CASSETTE Alert	1. Application - Improperly primed I.V. administration set. - Improper loading of cassette. Before closing cassette door, the drip chamber of the infusion set must be higher than the pump and all roller clamps between the drip chamber and the pump must be opened. After the cassette door is closed, the fluid container may be lowered if desired. - Air degassing from the I.V. fluid. 2. Calibration - Air In Cassette Alert Sensitivity (Section 3.1.3) 3. Bellows Assembly 4. Pump Module Interface Board 5. Microprocessor Board
Low Volume Infused	1. Application - Pressure or restrictions in the patient side line. (Typically caused by clogged in-line filters, almost completely closed clamps, or small patient catheter in conjunction with high flow rates.) - Vacuum in the bottle side line due to inadequate venting into the solution container. - Solution container too low with respect to the patient. - Particulate matter in the solution, causing improper cassette function. - Air in the cassette, below the detectable limit. - Restrictions in the bottle side line. (Typically from a micro-drop cannula) - Dirty receptacle membranes or actuator pins. - Viscous solutions. - Incorrect flow rate settings by the operator. Note: Determining volumetric accuracy in a clinical setting is difficult because the only readily available points of comparison are disposable burettes and IV containers. Using burettes or solutions containers to measure accuracy can result in an error of five percent or more, making these devices inappropriate for determining pump accuracy unless extreme delivery errors occurs. 2. Calibration - Volumetric Accuracy (Section 3.1.4)

SYMPTOM	POSSIBLE CAUSES
High Volume Infused	1. Application - Particulate matter in the solution, causing improper cassette function. - Incorrect flow rate settings by the operator. Note: Determining volumetric accuracy in a clinical setting is difficult because the only readily available points of comparison are disposable burettes and IV containers. Using burettes or solutions containers to measure accuracy can result in an error of five percent or more, making these devices inappropriate for determining pump accuracy unless extreme delivery errors occur. 2. Calibration - Volumetric Accuracy (Section 3.1.4)
False Cassette/Door Alert	1. Adjustment - Cassette Door Switch Adjustment (Section 6.2.5) 2. Cassette Door Switch 3. Microprocessor Board 4. Power Management Board
Pressure Cal Error: *INVALID OP LIMIT*	1. Bellows Assembly 2. Pump Module Interface Board 3. Microprocessor Board
Pressure Cal Error: *INVALID UP LIMIT*	1. Bellows Assembly 2. Pump Module Interface Board 3. Microprocessor Board
Pressure Cal Error: *INVALID NEG VANE EDGE*	1. Pump Module Interface Board 2. Motor Cam Vane Alignment 3. Bellows Assembly 4. Microprocessor Board 5. Motor

SYMPTOM	POSSIBLE CAUSES
Pressure Cal Error: *INVALID POS VANE EDGE*	1. Pump Module Interface Board 2. Motor Cam Vane Alignment 3. Bellows Assembly 4. Microprocessor Board 5. Motor
Air Detect Cal Error: *INVALID AIR DETECT PT*	1. Air in the cassette used for calibration. 2. Bellows Assembly 3. Pump Module Interface Board 4. Microprocessor Board
Volumetric Cal Error: *> 5% ERROR...*	1. Air in the cassette used for calibration. 2. Improper calibration during last maintenance check. 3. The I.V. administration set used for calibration. 4. Bellows Assembly Note: After the Bellows Assembly is replaced, it isnormal to see this message during the initial calibration of the new Bellows Assembly. Press ADJUST OPTION when this message appears to accept the new calibration value.
Volumetric Cal Error: *INVALID VOL...*	1. Air in the cassette used for calibration. 2. Improper Calibration during last maintenance check. 3. The I.V. administration set used for calibration. 4. Bellows Assembly
Inoperative control panel switch.	1. Control Panel 2. Display Board 3. Microprocessor Board 4. Parent Board and associated cables and connectors.
Inoperative digital or aplha-numeric display.	1. Display Board 2. Microprocessor Board 3. Parent Board and associated cables and connectors.

SYMPTOM	POSSIBLE CAUSES
One channel will not power on, other channels function properly.	1. Control Panel 2. Power Management Board 3. Microprocessor Board 4. Parent Board and associated cables and connectors.
No channels will power on, CHARGE indicator is off when connected to AC power.	1. Power Supply Board 2. Power Management Board 3. Internal Wiring Harness
No channels will power on when not connected to AC power.	1. Battery Fuse 2. Discharged Main Battery 3. Internal Wiring Harness
Battery will not charge, CHARGE indicator is on when connected to AC power.	1. Main Battery 2. Power Management Board
The buzzer is active instead of the audible BING-BONG alert.	1. Common Board 2. Speaker 3. Internal Wiring Harness
Back up buzzer inoperative.	1. Buzzer 2. Common Board 3. Power Management Board 4. Internal Wiring Harness
Audio alert volume will not adjust.	1. Common Board
NO BATTERY BACKUP Message	1. Common System Check
BAT CAL NEEDED Message	1. Battery Calibration (Section 3.1.18)
REPLACE BAT Message	1. Weak Battery
CHARGE BATTERY Message	1. Discharged Battery 2. Battery Fuse Has Been Removed
UNKNOWN BATTERY STATUS - OPERATE ON AC POWER Message	1. Common System Check

SYMPTOM	POSSIBLE CAUSES
CHANNEL SYSTEM CHECK with solid indicator. (See notes next page)	1. Power Management Board 2. Microprocessor Board.
CHANNEL SYSTEM CHECK with flashing indicator. (See notes next page)	
Error Codes:	
01, 02, 03, 04, 07, 08 09, 10, 12, 13, 14, 17 18, 24, 25, 26, 32	1. Microprocessor Board
05, 06	1. Microprocessor Board 2. Display Board 3. Control Panel
11, 30, 31	1. Microprocessor Board 2. Display Board
15, 16, 19, 20, 22	1. Pump Module 2. Microprocessor Board 3. Power Management Board
23, 27, 28	1. Microprocessor Board 2. Power Management Board
21	1. Pump Module 2. Microprocessor Board
29	1. Common Board 2. Microprocessor Board 3. Display Board

SYMPTOM	POSSIBLE CAUSES
COMMON SYSTEM CHECK (See notes below)	
Error Codes:	
A, B, D, E, F, H, I J, K, L, M, O, S, T	1. Common Board 2. Microprocessor Board
G, Q, R	1. Common Board 2. Microprocessor Board 3. Power Management Board 4. Pump Module
N	1. Power Management Board 2. Microprocessor Board 3. Common Board
P	1. Battery Circuit (Fuse removed while running on AC power) 2. Power Management Board 3. Microprocessor Board 4. Power Supply Board

SYSTEM CHECK NOTES:

1. A solid CHANNEL SYSTEM CHECK indicator occurs when the Power Management Board logic senses a malfunction. There are no associated error codes. A flashing CHANNEL SYSTEM CHECK indicator occurs when the software senses a malfunction and records an error code which can be viewed at a later time.

2. The SYSTEM CHECK and COMMON SYSTEM CHECK error codes should be used as a guideline for determining the source of a problem in a pump. Board level troubleshooting should be performed when recurring SYSTEM CHECK alerts occur. SYSTEM CHECK and COMMON SYSTEM CHECK alerts may not be indicative of a hardware failure in the pump. Infrequent, non-recurring faults might be induced by environmental factors, such as electrostatic discharge or electromagnetic radiation.

3. The probable causes shown above are the most likely causes of the conditions resulting in the error codes. Errors might also be caused by defective regulators on the Power Management Board (check DC voltages and ripple voltages), or by interconnections between the boards and other cables and connectors.

4. The I^2C bus operation states are to be used in conjunction with the COMMON SYSTEM CHECK error codes to help determine the source of a problem. The I^2C bus is shared by all of the boards in the pump except the Display Board and the Power Supply Board. If the COMMON SYSTEM CHECK error code indicates an I^2C bus problem, the common bus operation states codes may indicate which device was being accessed at the time the error occurred, and thus which board is the most likely source of the problem.

5. A description of each error code can be found starting on page 4-8. A description of the common bus operation states codes can be found on page 4-11. See page 1-2 to view error codes.

CHANNEL SYSTEM CHECK Error Codes

00 NO ERROR
No system check error condition exists.
01 RETURN TO STARTUP
Program execution control has returned to the startup code.
02 CAM FULL
There is no room in the microprocessor Content Addressable Memory to place an entry.
03 ILLEGAL SCHEDULER CALL
A task has tried to pause or block another task illegally.
04 UNDEFINED CASE
An undefined case clause of a switch statement has been executed.
05 UNDEFINED KEY
An undefined keypress has been detected.
06 FULL PIPE
An attempt to write to a pipe was made but the pipe was full.
07 ILLEGAL OPCODE
An un-implemented microprocessor opcode was executed.
08 TASK IDLE TOO LONG
A task has failed its Task Execution test and has remained idle too long.
09 CRITICAL DATA BLOCK COMPARE ERROR
The critical data block and the critical data block copy did not compare correctly or verification of the checksum of the critical data block failed.
10 NO SWITCH TO KVO RATE
The channel failed to switch to the KVO rate after delivery to a VTBI of zero.
11 CHANNEL ID COMPARE ERROR
The channel has failed its test for channel ID verification.
12 INVALID STATE
An invalid combination of states occurred during program execution.
13 MSR CALCULATION ERROR
A motor-step-rate, calculation error has occurred during processing.
14 INVALID TASK EXECUTION
The power on self test task has executed outside of the powerup sequence.
15 ABSOLUTE MOTOR POSITION ERROR
The absolute position sensor has returned a value that is not appropriate for the current motor step count range.
16 RELATIVE MOTOR POSITION ERROR
The motor motion sensor has returned a value that does not correspond to the current motor rate.
17 ADC TIMEOUT ERROR
The analog to digital Converter has failed to convert within the allotted time.
18 ADC NO START ERROR
The ADC cannot start an analog-to-digital conversion.
19 MOTOR RATE ERROR
A motor rate error has been detected during the Redundant Motor Rate Check.
20 PUMP MODULE SWITCH ERROR
An invalid combination of pump module cassette-loaded switch states was detected.
21 EEPROM ACCESS ERROR
The I^2C controller is unable to access the EEPROM on the pump module board.
22 INVALID SLOPE
The lower reference pressure reading is higher than the higher reference pressure reading when calculating the slope of the pressure curve during benchmarking.
23 ADC REFERENCE VOLTAGE ERROR
An analog-to-digital conversion of the 2.5V reference voltage signal was incorrect.
24 TIMEBASE ERROR
A mismatch between the microprocessor system clock and the I^2C controller clock has been detected.
25 INVALID POINTER
The motor step pointer has been incremented outside of the motor step table.
26 ZERO FLOW RATE CALCULATION ERROR
The motor step rate calculation has attempted a divide by zero.
27 PRIMARY WATCHDOG TIMER FAILURE
The primary watchdog timer failed during powerdown.

CHANNEL SYSTEM CHECK Error Codes (cont)

28 REDUNDANT WATCHDOG TIMER FAILURE
The redundant watchdog timer failed during powerdown.

29 INVALID ALIVE COUNTER
Multiple channels are modifying the same alive counter value in the Common Board RAM.

30 EEPROM ADDRESS ERROR
The channel ID input from the Display Board is not the same as the channel ID used to initialize the EEPROM slave address.

31 INVALID CHANNEL ID
An invalid channel ID was read from the Display Board.

32 VOLUME COUNTERS CALCULATION ERROR
An error in the calculation of the amount of fluid delivered per step has occurred.

33 UNDEFINED ERROR CODE
The numerical end of valid error codes.

COMMON SYSTEM CHECK Error Codes

- NO COMMON SYSTEM ERROR
  No common system check error condition has occured or currently exists.
- A COMMON STATE CHECKSUM ERROR
  A checksum failure of the common states buffer in the common board RAM occurred.
- B COMMON STATE RANGE CHECK ERROR
  The range check of the fields of the common state buffer failed.
- C COMMON LED ERROR
  A channel has declared a common system error based on having detected that another channel has declared an error and has activated the common LED. This is a normal error code which will be displayed when more than one channel is on and one has a COMMON SYSTEM CHECK.
- D BATTERY DATA CHECKSUM ERROR
  A checksum failure of the battery data buffer in the common board RAM occurred.
- E CHANNEL STATE CHECKSUM ERROR
  A checksum failure of the channel state buffer in the common board RAM occurred.
- F TIMESLOT LEADING EDGE INVALID OPERATION STATE ERROR
  An I^2C bus operation was in progress on a channel at the time that a leading edge timeslot interrupt occurred.
- G TIMESLOT TRAILING EDGE INVALID OPERATION STATE ERROR
  An I^2C bus operation was in progress on a channel at the time that a trailing edge timeslot interrupt occurred. This can be caused by a hardware SYSTEM CHECK (watchdog reset or power fail condition) in one channel when other channels are turned on. (Hardware SYSTEM CHECK produces a solid indicator)
- H I^2C ISR NO OPERATION ERROR
  An interrupt occurred on the I^2C bus at a time when no I^2C bus operations were in progress or expected.
- I NEXT I^2C MESSAGE BUS BUSY ERROR
  The I^2C bus was busy and stayed busy at the time when an I^2C message was to be initiated.
- J POST TASK I^2C LOGON ERROR
  A channel has not logged onto the I^2C bus by the execution time of the POST Task. (Power on self test)
- K WATCHDOG TIMESLOT NOT RECEIVED ERROR
  A timeslot interrupt was not received by a channel within its expected time.
- L WATCHDOG TIMESLOT LONG DURATION ERROR
  The Watchdog Task has detected that the calculated length of a channel's timeslot was longer than the maximum acceptable timeslot interval.
- M WATCHDOG TIMESLOT SHORT DURATION ERROR
  The Watchdog Task has detected that the calculated length of a channel's timeslot was shorter than the minimum acceptable timeslot interval.
- N BATTERY CIRCUIT FAILURE
  The deviation between the battery voltages that are reported between each channel within the common board RAM is greater than the acceptable limits.
- O COMMON STATES COMPARE ERROR
  A channel has detected a mismatch between its local copy of the common states and the common states which reside in the common board RAM. This can be caused by pressing INFUSE/PAUSE and then immediately adjusting the rate limit.
- P BATTERY CHARGE ERROR
  A mismatch between the line and charge LEDs has been detected. This is a probable indication that the battery fuse has been removed from the pump while running on line power.
- Q LRB ERROR
  An LRB error (Last Received Bit) was detected during the transmission of a message across the I^2C-bus. This is indicative of a slave device not acknowledging a message transmitted on the I^2C Bus.
- R I^2C BUS ERROR
  A BER error (Bus Error) was detected during the transmission of a message across the I^2C bus.
- S I^2C TIMESLOT SHORT DURATION ERROR
  The I^2C Task has detected that the calculated length of a channel's timeslot was shorter than the minimum acceptable timeslot interval.
- T MICRO RATE INFUSION ERROR
  The flow rate value of a channel and the flow rate mode value of a channel are in conflict. (The flow rate mode indicates MICRO mode, but the flow rate is greater than 99.9).
- U UNDEFINED COMMON SYSTEM ERROR CODE
  The end of valid error codes.

Common Bus (I^2C) Operation States

- NO ERROR CONDITION
  No common system check error condition has occured or currently exists.
- A READING CHANNEL PUMP BUFFER
  The channel pump buffer is currently being read from the common board RAM.
- B READING CHANNEL STATES BUFFER
  The channel states buffer is currently being read from the common board RAM.
- C READING COMMON STATES BUFFER
  The common states buffer is currently being read from the common board RAM.
- D READING BATTERY DATA BUFFER
  The battery data buffer is currently being read from the common board RAM.
- E READING RTC
  The real-time clock is currently being read from the common board RAM.
- F READING I/O REGISTER 1
  I/O port 1 on the power management board is currently being read.
- G READING I/O REGISTER 2
  I/O port 2 on the common board is currently being read.
- H READING BATTERY STAMP BUFFER
  The battery timestamp buffer is currently being read from the common board RAM.
- I READING MSG 2 BLOCK
  Message 2 data block is currently being read from the common board RAM.
- J READING ERROR CODES BUFFER
  The error codes buffer is currently being read from the common board RAM.
- K WRITING I/O REGISTER 1A
  I/O port 1 on the power management board is currently being written for the first half of the sequence in which the power fail bit is written.
- L WRITING I/O REGISTER 1B
  I/O port 1 on the power management board is currently being written for the second half of the sequence in which the power fail bit is written.
- M WRITING I/O REGISTER 2
  I/O port 2 on the common board is currently being written.
- N WRITING CONTROL STATUS
  The control status word is currently being written to the common board RAM.
- O WRITING CHANNEL PUMP BUFFER
  The channel pump buffer is currently being written to the common board RAM.
- P WRITING CHANNEL STATES BUFFER
  The channel states buffer is currently being written to the common board RAM.
- Q WRITING COMMON STATES BUFFER
  The common states buffer is currently being written to the common board RAM.
- R WRITING BATTERY DATA BUFFER
  The battery data buffer is currently being written to the common board RAM.
- S WRITING BATTERY STAMP BUFFER
  The battery timestamp buffer is currently being written to the common board RAM.
- T WRITING RTC
  The real-time clock is currently being written to the common board RAM.
- U WRITING ERROR CODES BUFFER
  The error codes buffer is currently being written to the common board RAM.
- V WRITING EEPROM
  The calibration constants are currently being written to the pump module EEPROM.
- W READING EEPROM
  The calibration constants are currently being read from the pump module EEPROM.
- X NO OPERATION
  No message transmission is currently occurring across the I^2C bus. This is a normal operation state if the COMMON SYSTEM CHECK was not induced by an I^2C error on this channel.
- Y NO OPERATION I^2C TASK SCHEDULED
  The initial read operations have all been successfully performed and the I^2C task has been scheduled.
- Z UNDEFINED OPERATION STATE
  The numerical end of valid operation states.

4.2

Circuit Board Test Points

Many of the important signals are routed to test points on the circuit boards. This allows for easy access to the signals when troubleshooting. Listed in this section are the available test points and a description of each signal.

Test Point	Label	Description
1	GND	Power and logic ground. Unless otherwise specified, all other test point signals are referred to these pins.
2	AG	Analog ground. This is the reference for the microprocessor analog to digital converter, and for all analog circuits on the Microprocessor Board and Pump Module Interface Board.
3	2.5V	Precision 2.500 volt reference used for battery voltage and current measurements and as a check of the Microprocessor Board supply voltage and A/D converter integrity. The voltage between this test point and analog ground should be 2.48 to 2.52 volts DC.
4	SC	Microprocessor Board I^2C bus serial clock line, connected to the pump module I^2C memory and may be switched onto the common I^2C bus, which is shared by all three Microprocessor Boards, the Common Board, and the Power Management Board. The signal on this test point and the SD test point are nominally 0-to-5 volts when the Microprocessor Board is communicating with the pump module, the Common Board or the Power Management Board I^2C components, and should be about 5 volts during intervals between communications.
5	SD	Microprocessor Board I^2C bus serial data line. See test point 4, SC, above.
6	1.5M	1.5 MHz clock used for check of microprocessor clock frequency. This 0-to-5 volt square wave is derived from the 3.0 MHz I^2C bus controller clock on the Microprocessor Board. The frequency of this signal should be 1.500 MHz +/-0.1%.
7	W1	Watchdog timer #1 reset signal. This 0-to-5 volt signal should make a transition about every 2 milliseconds to prevent a watchdog timeout on the channel. The signal is driven by a software function independent of the function driving watchdog timer #2 reset.
8	W2	Watchdog timer #2 reset signal. This 0-to-5 volt signal should make a transition about every 10 milliseconds to prevent a watchdog timeout on the channel. The signal is driven by a software function independent of the function driving watchdog timer #1 reset.
9	RS	Channel microprocessor reset signal. This signal is active low for 50 milliseconds after the channel is turned on, and remains inactive (5 volts) during normal operation of the channel. In the event that a watchdog timeout occurs because one of the watchdog timers was not petted in time or CHnVCC drops below 4.62 +/- 0.12 VDC, the signal goes active, resetting the microprocessor and display circuits, and turns off the channel power with a power fail alarm.

Test Point	Label	Description
10	MT	Motor current control signal. The microprocessor sets this voltage to control the motor current limit, and thus the motor torque, as required during the pumping cycle. The voltage at this pin will normally be one of the following levels:

Motor Step	Description	Nominal Voltage (VDC)
-	Startup	2.71
5-60	Refill	2.08
61-200	Early Delivery	1.22
201-400, 1-4	Late Delivery	1.67

11	VB	Battery voltage signal, referred to analog ground. This voltage is nominally 6.00 volts less than the battery voltage. This signal is present only when the channel is turned on.
12	IB	Battery current signal, referred to analog ground. This voltage is nominally 2.0 times the battery current (in amps) when the battery is charging, and 2.5 times the battery current when the pump is running on battery power. This signal is present only when the channel is turned on.
13	PR	Bellows pressure signal from the Pump Module Interface Board. This voltage is proportional to the pump module bellows pressure, and is nominally 1.0 volt at 0 psig, scaled to a nominal 0.076 volt/psi.
14	VR	Analog circuit reference voltage. This voltage is filtered from the 5 volt logic supply voltage, and provides the reference voltage for the microprocessor analog to digital converter and for the pressure transducer current source on the Pump Module Interface Board. The voltage at this test point should be 4.75 to 5.25 VDC with a maximum ripple of 20 mV peak-to-peak.
15	+5V	+5 volt logic supply for the Microprocessor Board, pump module and channel displays. This voltage is present whenever the channel is turned on, and should be 4.85 to 5.15 VDC with less than 100 mV peak-to-peak ripple.

Test Point	Label	Description
TP1-1	PR	Bellows pressure signal to the Microprocessor Board. This voltage is proportional to the pump module bellows pressure, and is nominally 1.0 volt at 0 psig, scaled to a nominal 0.076 volt/psi.
TP1-2	AG	Analog ground. This is the reference ground for the pressure transducer and amplifier circuits on the Pump Module Interface Board and the microprocessor A/D converter.
TP1-3	MT	Motor current control signal. The microprocessor sets this voltage to control the motor current limit, and thus the motor torque, as required during the pumping cycle. The voltage at this pin will normally be one of the following levels:
TP1-4	8V	8 volt DC power for the pressure amplifier. This voltage is regulated from the motor supply voltage and should be 7.20 to 8.80 volts DC with no more than 25 mV peak-to-peak ripple.
TP1-5	5V	Logic supply voltage for the pump module logic. This voltage is present whenever the channel is turned on, and should be 4.85 to 5.15 VDC with less than 100 mV peak-to-peak ripple.
TP2-1	MI+	Motor motion sense LED positive current sense. The voltage between this test point and TP2-2 (MI-) is proportional to the current in the motion sense LED. These test points are used in the adjustment of the motor motion sensor circuit, section 6.2.1.
TP2-2	MI-	Motor motion sense LED negative current sense. See test point TP2-1 (MI+).
TP2-3	MC	Motor motion sense optical switch collector. The voltage at this point should be near 5 VDC when the optical path is fully blocked, and <0.5 VDC when fully unblocked.
TP2-4	MS	Motor motion sense comparator output to Microprocessor Board. This test point is used in the adjustment of the motor motion sensor circuit, section 6.2.1.
TP2-5	GND	Pump Module Interface Board power and logic ground.

Motor Step	Description	Nominal Voltage (VDC)
-	Startup	2.71
5-60	Refill	2.08
61-200	Early Delivery	1.22
201-400, 1-4	Late Delivery	1.67

Test Point	Label	Description
TP3-1	PI+	Motor position sense LED positive current sense. The voltage between this test point and TP3-2 (PI-) is proportional to the current in the position sense LED. These test points are used in the adjustment of the ' motor position sensor circuit, section 6.2.2.
TP3-2	PI-	Motor position sense LED negative current sense. See test point TP3-1 (PI+).
TP3-3	PC	Motor position sense optical switch collector. The voltage at this point should be near 5 VDC when the optical path is fully blocked, and <0.5 VDC when fully unblocked.
TP3-4	PS	Motor position sense comparator output to Microprocessor Board. This test point is used in the adjustment of the motor position sensor circuit, section 6.2.2.
TP3-5	GND	Pump Module Interface Board power and logic ground.

Test Point	Label	Description
1,2	GND	Power and logic ground. Unless otherwise specified, all other test point signals are referred to these pins.
3	+5V	Common circuit power supply voltage from Power Management Board. This voltage is present whenever the pump is plugged into AC line power or when one or more channels is turned on, and should be 4.85 to 5.15 VDC with less than 100 mV peak-to-peak ripple.
4	SDA	Common I^2C bus serial data line, shared by all three Microprocessor Boards, the Common Board, and the Power Management Board. The signal on this test point and the SCL test point are nominally 0-to-5 volts when a Microprocessor Board is communicating with either the Common Board or Power Management Board I^2C components, and should be about 5 volts during intervals between communications.
5	SCL	Common I^2C bus serial clock line. See test point 4, SDA, above.
6	LOK	Output of lockout switch debounce circuit. This signal is normally 0 volts until the rear panel lockout switch is closed. The closure of the lockout switch initiates a 5 volt pulse with a nominal duration of 670 milliseconds.
7	BCK	Clock signal for the audible alarm circuit. This signal is a rectangular wave with a 0-to-5 volt amplitude and a nominal frequency of 17.241 kHz.
8	TCK	Time slot clock. This signal is a square wave with a 0-to-5 volt amplitude and nominal frequency of 7.63 Hz. (Early versions used a 8 Hz +/-20% clock)
9	CH1	Channel 1 time slot. This signal is a 33% duty cycle 0-to-5 volt signal with a nominal period of 393 milliseconds. When this signal is high, the channel 2 and 3 time slot signals should be low. This signal is active only when channel 1 is turned on. (Early versions used a signal with a period of 375 millisecond +/- 20%)
10	CH2	Channel 2 time slot. This signal is a 33% duty cycle 0-to-5 volt signal with a nominal period of 393 milliseconds. When this signal is high, the channel 1 and 3 time slot signals should be low. This signal is active only when channel 2 is turned on. (Early versions used a signal with a period of 375 millisecond +/- 20%)
11	CH3	Channel 3 time slot. This signal is a 33% duty cycle 0-to-5 volt signal with a nominal period of 393 milliseconds. When this signal is high, the channel 1 and 2 time slot signals should be low. There is a short duration glitch on this signal at the time that the channel 1 time slot goes low and the channel 2 time slot goes high; this is normal operation. This signal is active only when channel 3 is turned on. (Early versions used a signal with a period of 375 millisecond +/- 20%)

Test Point	Label	Description
12	SAV	Supply voltage for the audible alarm amplifier. This voltage is present whenever the pump is plugged into AC line power or whenever any channel is turned on. The voltage at this test point should be greater than 11 volts when the pump is plugged into AC line power, and greater than the battery voltage minus 1 volt when operating on battery power.
13	R5V	Supply voltage for the common shared memory. This voltage should exceed 4.25 volts DC when the pump is plugged into AC line power or when the pump is operating on battery power. If the pump is turned off and not connected to AC line power, the voltage at this point should exceed 2.30 volts DC.
14	AIN	Audible alarm amplifier input. This test point may be grounded when an audible alarm is occurring for the purpose of testing the alarm backup circuit.
15	-5V	Common Board -5 volt analog supply. This voltage is generated from a switched capacitor voltage converter followed by a linear -5 volt regulator, and provides negative rail power for the audible alarm circuit. This voltage is present whenever the pump is plugged into AC line power or when one or more channels is turned on, and should be -4.75 to -5.25 VDC with less than 100 mV peak-to-peak ripple.

Test Point	Label	Description
1,2	G	Power and logic ground. Unless otherwise specified, all other test point signals are referred to these pins.
3	AG	Analog ground. Reference for all analog circuits on Power Management Board, Microprocessor Boards and the Pump Module Interface Boards.
4	VB	Output of the battery voltage amplifier, referred to analog ground. This voltage is nominally 6.00 volts less than the battery voltage. This signal is present whenever the pump is plugged into AC line power or when one or more channels is turned on.
5	IB	Output of the battery current amplifier, referred to analog ground. This voltage is nominally 2.0 times the battery current (in amps) when the battery is charging, and 2.5 times the battery current when the pump is running on battery power. This signal is present whenever the pump is plugged into AC line power or when one or more channels is turned on.
6	CF	Output of the battery charge counter voltage-to-frequency converter. This is a square wave with an amplitude of 0-to-5 volts DC, and a frequency proportional to the battery current. The input to the voltage-to-frequency converter is the battery current amplifier output signal. The voltage to frequency converter is scaled such that its output frequency is nominally 37283 Hz with an input voltage of 5.0 volts DC. This signal is present whenever the pump is plugged into AC line power or when one or more channels is turned on.
7	VU	Unregulated, switched main power for the pump voltage regulators. This voltage should be about 0.6 volt less than the power supply voltage when the pump is plugged into AC line power, or about 0.6 volt less than the battery voltage when the pump is operating on battery voltage (one or more channels on).
8	5S	5 volt standby regulator output. This voltage provides power for the power control and alarm logic and the battery charge counter. The voltage is present unless the pump is unplugged from AC line power and the battery circuit is opened, and should be 4.85 to 5.15 VDC with less than 100 mV peak-to-peak ripple.
9	+5	Power management and common circuit voltage regulator output. This switching regulator provides power for the I^2C interface on the Power Management Board, all the circuits on the Common Board, and the channel system check LEDs on the Display Board. This voltage is present whenever the pump is plugged into AC line power or when one or more channels is turned on, and should be 4.85 to 5.15 VDC with less than 100 mV peak-to-peak ripple.

Test Point	Label	Description
10	15	Power management +15 volt analog supply. This switching regulator provides power for the battery monitoring circuits and the channel on signals provided to the Microprocessor Boards to turn on their analog input switches. This voltage is present whenever the pump is plugged into AC line power or when one or more channels is turned on, and should be 14.25 to 15.75 VDC with less than 100 mV peak-to-peak ripple.
11	-5	Power management -5 volt analog supply. This voltage is generated from a switched capacitor voltage converter followed by a linear -5 volt regulator, and provides negative rail power for the battery voltage comparator, battery current amplifier and battery sense circuit. This voltage is present whenever the pump is plugged into AC line power or when one or more channels is turned on, and should be -4.75 to -5.25 VDC with less than 100 mV peak-to-peak ripple.
12	VM	+12 volt motor voltage regulator output. This switching regulator output provides a regulated voltage for the stepper motors used in the pump modules. This voltage is present whenever the pump is plugged into AC line power or when one or more channels is turned on, and should be 11.50 to 12.50 VDC with less than 200 mV peak-to-peak ripple.
13	V1	Channel 1 +5 volt regulator output. This switching regulator provides the logic supply for the channel 1 Microprocessor Board, Pump Module Interface Board, and Displays. This voltage is present whenever channel 1 is turned on, and should be 4.85 to 5.15 VDC with less than 100 mV peak-to peak ripple.
14	V2	Channel 2 +5 volt regulator output. This switching regulator provides the logic supply for the channel 2 Microprocessor Board, Pump Module Interface Board, and Displays. This voltage is present whenever channel2 is turned on, and should be 4.85 to 5.15 VDC with less than 100 mV peak-to-peak ripple.
15	V3	Channel 3 +5 volt regulator output. This switching regulator provides the logic supply for the channel 3 Microprocessor Board, Pump Module Interface Board, and Displays. This voltage is present whenever channel 3 is turned on, and should be 4.85 to 5.15 VDC with less than 100 mV peak-to-peak ripple.
16	B+	Positive battery voltage. The voltage between this test point and the negative battery voltage test point is equal to the battery voltage less any resistive drops in the battery circuit.
17	B-	Negative battery voltage. The voltage between this test point and analog ground is proportional to the battery current. ($V_{B-}=0.1 * I_{BAT}$)

Section 5.0
Parts Replacement Procedures

Overview

This section contains procedures for replacing various subassemblies. To avoid duplication, the procedure for opening and closing the case is shown on the following page and will not be included in each of the parts replacement procedures.

Reference the following drawings as needed when performing the procedures in this section:

- Front Case Assembly, page 7-27 to 7-28
- Front Panel Assembly, page 7-29
- Rear Case Assembly, page 7-30 to 7-32
- Pump Module Assembly, page 7-26

Cautions:

Electronic components may be damaged by static electricity discharges. Open the case and perform testing only at an ESD controlled work station using an electrically dissipative grounded mat and wrist strap.

To avoid risk of electric shock, do not come into contact with the primary AC circuitry on the power supply mounted on the rear case at any time AC power is applied.

To avoid damage to electronic components, unplug the AC power cord and remove the battery fuse to electrically disconnect the battery whenever removing circuit boards.

The rear case must be positioned away from the front case during testing to assure that the rear case does not short out on the pump module circuit board for Channel 1.

Verify that the rubber gasket between the two case halves is in place before closing the case. If the gasket is not installed, fluid could enter the unit or the unit could become susceptible to static discharges. Either of these conditions could result in erratic operation of the pump.

Prior to closing the case, verify that all the circuit boards are fully seated, that the ribbon cables connecting the Pump Modules to the Microprocessor Boards are fully seated, and that all wires are dressed such that they do not interfere with any moving parts in the pump and are clear of pinch points when the case halves mate.

Note:

When replacing circuit boards, pump modules, or bellows assemblies record the serial number of the replacement parts in your records. For easy reference, the serial number is printed on the part number label which is attached to the packaging of each replacement assembly.

Open The Case:

1. Disconnect the unit from AC power and remove the battery fuse from the holder on the rear case.

2. Using a 5/32" Allen wrench, remove the four screws securing the two halves of the pump and carefully separate the two halves to allow access to the inside of the pump.

Close The Case:

1. Verify that the pump is is disconnected from AC power and the battery fuse is removed.

2. Assure that all wires are dressed such that they do not interfere with any moving parts in the pump and are clear of pinch points when the case halves mate.

3. Position the two halves of the pump together and install the four screws, which were removed in step 2, to secure the pump housing together.

   Note: Ensure that the lock washers are present on all four screws.

   Caution: Over tightening screws may damage pump housings.

4. Reinstall the battery fuse.

Microprocessor Board

Removal:

Caution: To avoid damage to electronic components and the risk of electrical shock, disconnect the pump from the AC power and remove the battery fuse before opening the case.

1. Open the case.
2. Grasp the Microprocessor Board at the plastic board extractor and pull straight out.
3. Disconnect the Pump Module ribbon cable at connector P1 on the Microprocessor Board.

Replacement:

4. Connect the Pump Module ribbon cable connector to P1.
5. Align the Microprocessor Board between the top and bottom card guide ribs in the case and press on the plastic board extractor to fully seat the board into the mating connector.

Adjustment/ Verification:

6. If a fully functional replacement board was installed:

   - Close the case.
   - Perform the Periodic Maintenance Procedure, section 3.1.

7. If a functional defect was repaired on the circuit board:

   - Perform the Microprocessor Board Test Procedure, section 6.1.
   - Perform the Periodic Maintenance Procedure, section 3.1.

Control Panel/ Display Board

Removal:

Caution: To avoid damage to electronic components and the risk of electrical shock, disconnect the pump from the AC power and remove the battery fuse before opening the case.

1. Open the case.
2. Using a 1/4" nut driver, remove the four hex nuts with captive lock washers securing the Control Panel/Display Board to the pump case and push the Control Panel Assembly forward. It may be necessary to push forward on the Control Panel Assembly screws to dislodge the Control Panel Assembly from the pump.
3. Unplug the three ribbon cables connected to the Display Board and remove the Control Panel Assembly.
4. Lay the Control Panel/Display Board assembly face down on a flat surface. Using a 1/4" nut driver, remove the four hex nuts with captive lock washers and the four nylon insulating washers securing the Display Board to the Control Panel.
5. Unplug the Display Board from the connector at the bottom of the Control Panel.

   Caution: To avoid damaging the printed circuitry or bending the connector pins, do not pry apart with tools.

   To avoid damage to the alphanumeric displays, do not use organic based solvents such as alcohol to clean flux residue from the Display Board.

6. Remove the eight insulating spacers from the Control Panel.

Replacement:

7. Install the eight insulating spacers on the Control Panel.
8. Verify that the Display Board connector pins are straight and align connector J1 to the Control Panel connector. Press the connector together to fully mate.
9. Install the four nylon insulating washers on the four inner Display Board mounting studs then install four 1/4" hex nuts which were removed in step 4.

   Caution: Do not install the 1/4" nuts without installing the insulating washers. Printed circuitry on the Display Board may be damaged by the lock washers.

Control Panel/ Display Board(cont)

10. Reconnect the three ribbon cables to the Display Board. Verify correct pin alignment of the connectors before proceeding.

    Caution: Fold the ribbon cables to the Display Board for plug-in board clearance. Do not press on the cables too firmly; this could cause electrical shorts between the component leads and the cable.

11. Install the Control Panel/Display Board assembly and secure with the four 1/4" hex nuts which were removed in step 2.

Adjustment/ Verification:

12. Perform the ESD Suppressor Check, 6.5.1, of section 6.5.

13. Close the case.

14. Perform the Periodic Maintenance Procedure, section 3.1.

5.3

Pump Module

Removal:

Caution: To prevent damage to electrical components, turn off all channels and disconnect the pump from AC power before proceeding.

1. Using a 1/8" Allen wrench, remove the screw from the bottom of the case.

   Caution: To prevent damage to the safety ground connection, do not attempt to turn the large hex nut.

2. Open the cassette door. Grasp the door handle and slowly pull the pump module forward until the ribbon cable is visible. Considerable force may be needed to overcome the friction of the drip seal. Do not pull it out too far as there is a short cable connecting the Pump Module to the Microprocessor Board.

3. Remove the ribbon cable connector from the Pump Module Interface Board.

Replacement:

4. Verify that all channels are off and the pump is disconnected from AC power.

5. Connect the ribbon cable to the Pump Module Interface Board. Verify that the connector is fully seated.

6. Close the door handle and slide the Pump Module into the pump.

7. Reinstall the flat Allen head screw which was removed in step 1.

Adjustment/ Verification:

8. Perform the Periodic Maintenance Procedure, section 3.1.

Pump Module Interface Board

Removal:

Caution: To prevent damage to electrical components, turn off all channels and disconnect the pump from AC power before proceeding.

1. Remove the Pump Module per section 5.3.

2. Disconnect the pressure transducer from connector J3 and the motor from connector P2 on the Pump Module Interface Board.

3. Remove the three large Phillips head screws securing the Pump Module Interface Board to the Motor Plate and remove the board from the Pump Module. Do not remove the small screw securing the cassette door switch to the circuit board.

   Note: Do not remove or replace the optical sensors,U7 or U8. The position of the sensors are important and cannot be aligned properly in the field.

Replacement:

4. If a functional defect was repaired on the circuit board (except for the Cassette Door Switch), perform the Motor Motion Sensor test, 6.2.1, and the Motor Position Sensor test, 6.2.2, of section 6.2.

5. Align the locating holes in the Pump Module Interface Board with the two locator pins on the Motor Plate.

   Caution: Assure that the slotted optical switches clear the encoder disk and that the cassette door switch actuator straddles the cassette door switch.

6. Install the three Phillips head screws, which were removed in step 3, to secure the Pump Module Interface Board to the Motor Plate.

7. Connect the motor to connector P2 on the Pump Module Interface Board. The white motor wire is pin 1.

8. Using needle nose pliers or hemostats connect the pressure transducer to connector J3 on the Pump Module Interface Board.

   Caution: Use care not to damage the calibration resistor mounted on the pressure transducer connector.

   The white transducer wire is pin 1. Verify that neither the wires nor the connector interfere with the cam follower motion.

9. Verify that all channels are off and the pump is disconnected from AC power.

10. Connect the ribbon cable to the Pump Module Interface Board.

Adjustment/
Verification:

11. If a fully functional board was installed:

    - Perform the Cassette Door Switch Adjustment, 6.2.5 of section 6.2.
    - Reinstall the pump module per section 5.3.
    - Perform the Periodic Maintenance Procedure, section 3.1.

12. If a functional defect was repaired on the circuit board (except for the Cassette Door Switch):

    - Perform the +8.0 Volt Regulator Test, 6.2.3 of section 6.2.
    - Perform the Pressure Transducer Span/Offset Test, 6.2.4 of section 6.2.
    - Perform the Cassette Door Switch Adjustment, 6.2.5 of section 6.2.
    - Perform the Motor Torque Test, 6.2.6 of section 6.2.
    - Reinstall the Pump Module per section 5.3.
    - Perform the Motor Current Test, 6.2.7, of section 6.2.
    - Perform the Periodic Maintenance Procedure, section 3.1.

Cassette Door Switch

Removal:

Caution: To prevent damage to electrical components, turn off all channels and disconnect the pump from AC power before proceeding.

1. Remove the Pump Module per section 5.3.

2. Disconnect the pressure transducer from connector J3 and the motor from connector P2 on the Pump Module Interface Board.

3. Remove the three large Phillips head screws securing the Pump Module Interface Board to the Motor Plate and remove the board from the Pump Module.

4. Remove the Phillips head screw and nut securing SW1 to the Pump Module Interface Board.

5. Unsolder the three leads securing SW1 to the Pump Module Interface Board and remove the switch.

Replacement:

6. Position the switch leads in the board holes, insert the Phillips head screw, which was removed in step 4, from the circuit side of the board and attach the 2mm nut. Align the long side of the switch parallel to the edge of the board and torque the screw to 1.0 +/- 0.1 in-lb.

   Caution: Over tightening the screw may damage the switch.

7. Solder the switch leads and clean solder flux from the board using care not to contaminate the switch with fluid.

8. Align the locating holes in the Pump Module Interface Board with the two locator pins on the Motor Plate.

   Caution: Assure that the slotted optical switches clear the encoder disk and that the cassette door switch actuator straddles the cassette door switch.

9. Install the three Phillips head screws, which were removed in step 3, to secure the Pump Module Interface Board to the Motor Plate.

10. Connect the motor to connector P2 on the Pump Module Interface Board. The white motor wire is pin 1.

11. Using needle nose pliers or hemostats connect the pressure transducer to connector J3 on the Pump Module Interface Board.

    Caution: Use care not to damage the calibration resistor mounted on the pressure transducer connector.

    The white transducer wire is pin 1. Verify that neither the wires nor the connector interfere with the cam follower motion.

Cassette Door Switch (cont)

12. Connect the ribbon cable to the Pump Module Interface Board.

Adjustment/ Verification:

13. Perform the Cassette Door Switch Adjustment, 6.2.5 of section 6.2.

14. Reinstall the Pump Module per section 5.3.

15. Perform the Periodic Maintenance Procedure, section 3.1.

Motor/Cam Assembly

Removal:

Caution: To prevent damage to electrical components, turn off all channels before proceeding.

1. Remove the Pump Module per section 5.3.

2. Disconnect the pressure transducer from connector J3 and the motor from connector P2 on the Pump Module Interface Board.

3. Remove the three large Phillips head screws securing the Pump Module Interface Board to the Motor Plate and remove the board from the Pump Module. Do not remove the small screw securing the cassette door switch to the circuit board.

4. Remove the four Phillips flat head screws securing the Motor/Cam subassembly to the Receptacle Block.

5. Squeeze the side flanges of the Motor/Cam subassembly together with just enough force to clear the alignment locator pins and remove the subassembly from the Receptacle Block.

Replacement:

6. Squeeze the side flanges of the Motor/Cam subassembly together with just enough force to clear the alignment locator pins and position the subassembly on the Receptacle Block.

7. Install the four Phillips flat head screws, which were removed in step 4, to secure the Motor/Cam subassembly to the Receptacle Block.

8. Align the locating holes in the Pump Module Interface Board with the two locator pins on the Motor Plate.

   Caution: Assure that the slotted optical switches clear the encoder disk and that the cassette door switch actuator straddles the cassette door switch.

9. Install the three Phillips head screws, which were removed in step 3, to secure the Pump Module Interface Board to the Motor Plate.

10. Connect the motor to connector P2 on the Pump Module Interface Board. The white motor wire is pin 1.

11. Using needle nose pliers or hemostats connect the pressure transducer to connector J3 on the Pump Module Interface Board.

    Caution: Use care not to damage the calibration resistor mounted on the pressure transducer connector.

    The white transducer wire is pin 1. Verify that neither the wires nor the connector interfere with the cam follower motion.

12. Connect the ribbon cable to the Pump Module Interface Board.

Adjustment/ Verification:

13. Perform the Cassette Door Switch Adjustment, 6.2.5 of section 6.2.
14. Reinstall the Pump Module per section 5.3.
15. Perform the Motor Torque Test, 6.2.6 of section 6.2.
16. Perform the Periodic Maintenance Procedure, section 3.1.

5.7

Cam Follower

Removal:

Caution: To prevent damage to electrical components, turn off all channels before proceeding.

1. Remove the Pump Module per section 5.3.
2. Disconnect the pressure transducer from connector J3 and the motor from connector P2 on the Pump Module Interface Board.
3. Remove the three large Phillips head screws securing the Pump Module Interface Board to the Motor Plate and remove the board from the Pump Module. Do not remove the small screw securing the cassette door switch to the circuit board.
4. Remove the four Phillips flat head screws securing the Motor/Cam subassembly to the Receptacle Block.
5. Squeeze the side flanges of the Motor/Cam subassembly together with just enough force to clear the alignment locator pins and remove the subassembly from the Receptacle Block.
6. Place an adjustable wrench on the Rocker Arm. Remove the Phillips head screw securing the Cam Follower to the Rocker Arm.
7. Use an adjustable wrench or a 7/16" nut driver to hold the Cam Follower nut and remove the Phillips head screw from the Cam Follower.

Replacement:

8. Slide the the Phillips head screw through the Cam Follower, with the screw entering the Cam Follower on the side opposite of the hex nut, and turn the screw until it bottoms out on the Cam Follower.
9. Install the Cam Follower so that it is fully seated on the Rocker Arm.
10. Squeeze the side flanges of the Motor/Cam subassembly together with just enough force to clear the alignment locator pins and position the subassembly on the Receptacle Block.
11. Install the four Phillips flat head screws, which were removed in step 4, to secure the Motor/Cam subassembly to the Receptacle Block.
12. Align the locating holes in the Pump Module Interface Board with the two locator pins on the Motor Plate.

    Caution: Assure that the slotted optical switches clear the encoder disk and that the cassette door switch actuator straddles the cassette door switch.

13. Install the three Phillips head screws, which were removed in step 3, to secure the Pump Module Interface Board to the Motor Plate.

Cam Follower (cont)

14. Connect the motor to connector P2 on the Pump Module Interface Board. The white motor wire is pin 1.

15. Using needle nose pliers or hemostats connect the pressure transducer to connector J3 on the Pump Module Interface Board.

    Caution: Use care not to damage the calibration resistor mounted on the pressure transducer connector.

    The white transducer wire is pin 1. Verify that neither the wires nor the connector interfere with the cam follower motion.

16. Connect the ribbon cable to the Pump Module Interface Board.

Adjustment/ Verification:

17. Perform the Cassette Door Switch adjustment per section 6.2.5.

18. Reinstall the Pump Module per section 5.3.

19. Perform the Periodic Maintenance Procedure, section 3.1.

Bellows Assembly

Removal:

Caution: To prevent damage to electrical components, turn off all channels before proceeding.

1. Remove the Pump Module per section 5.3.

2. Disconnect the pressure transducer from connector J3 and the motor from connector P2 on the Pump Module Interface Board.

3. Remove the three large Phillips head screws securing the Pump Module Interface Board to the Motor Plate and remove the board from the Pump Module. Do not remove the small screw securing the cassette door switch to the circuit board.

4. Remove the four Phillips flat head screws securing the Motor/Cam subassembly to the Receptacle Block.

5. Squeeze the side flanges of the Motor/Cam subassembly together with just enough force to clear the alignment locator pins and remove the subassembly from the Receptacle Block.

6. Using a 7/64" Allen wrench, remove the two screws securing the Bellows Assembly to the Receptacle Block.

Replacement:

7. Position the Bellows Assembly in the Receptacle Block with the transducer leads toward the lower left corner of the Receptacle Block.

8. Rotate the Bellows Assembly to its most counter clockwise position and align the mounting holes. Install the two Allen head screws, which were removed in step 6, to secure the metal bellows. Alternate between the two screws when tightening to assure that the bellows membrane is flush with the Receptacle Block.

9. Squeeze the side flanges of the Motor/Cam subassembly together with just enough force to clear the alignment locator pins and position the subassembly on the Receptacle Block.

10. Install the four Phillips flat head screws, which were removed in step 4, to secure the Motor/Cam subassembly to the Receptacle Block.

11. Align the locating holes in the Pump Module Interface Board with the two locator pins on the Motor Plate.

    Caution: Assure that the slotted optical switches clear the encoder disk and that the cassette door switch actuator straddles the cassette door switch.

12. Install the three Phillips head screws, which were removed in step 3, to secure the Pump Module Interface Board to the Motor Plate.

Bellows Assembly (cont)

13. Connect the motor to connector P2 on the Pump Module Interface Board. The white motor wire is pin 1.

14. Using needle nose pliers or hemostats connect the pressure transducer to connector J3 on the Pump Module Interface Board.

    Caution: Use care not to damage the calibration resistor mounted on the pressure transducer connector.

    The white transducer wire is pin 1. Verify that neither the wires nor the connector interfere with the cam follower motion.

15. Connect the ribbon cable to the Pump Module Interface Board.

Adjustment/ Verification:

16. Perform the Cassette Door Switch Adjustment per section 6.2.5.

17. Reinstall the Pump Module per section 5.3.

18. Perform the Periodic Maintenance Procedure, section 3.1.

Common Board

Removal:

Caution: To avoid damage to electronic components and the risk of electrical shock, disconnect the pump from the AC power and remove the battery fuse before opening the case.

1. Open the case.

2. Grasp the Common Board at the plastic board extractor and pull straight out.

Replacement:

3. Align the Common Board between the top and bottom card guide ribs in the case and press on the plastic board extractor to fully seat the board into the mating connector.

Adjustment/ Verification:

4. If a fully functional replacement board was installed:

   - Close the case.
   - Perform the Periodic Maintenance Procedure, section 3.1.

5. If a functional defect was repaired on the circuit board:

   - Perform the Common Board Test Procedure, section 6.3.
   - Perform the Periodic Maintenance Procedure, section 3.1.

Power Management Board

Removal:

Caution: To avoid damage to electronic components and the risk of electrical shock, disconnect the pump from the AC power and remove the battery fuse before opening the case.

1. Open the case.

2. Grasp the Power Management Board at the plastic board extractor and pull straight out.

Replacement:

3. Align the Power Management Board between the top and bottom card guide ribs in the case and press on the plastic board extractor to fully seat the board into the mating connector.

Adjustment/ Verification:

4. If a fully functional replacement board was installed:

   - Close the case
   - Perform the Periodic Maintenance Procedure, section 3.1.

5. If a functional defect was repaired on the circuit board:

   - Perform the Power Management Bd Test Procedure, section 6.4.
   - Perform the Periodic Maintenance Procedure, section 3.1

Power Supply Board

Removal:

Caution: To avoid damage to electronic components and the risk of electrical shock, disconnect the pump from the AC power and remove the battery fuse before opening the case.

1. Open the case.
2. Verify that the AC power cord is unplugged.
3. Disconnect Power Supply secondary connector J2, primary connector J1 and ground quick disconnect P1.
4. Using a 7/64" Allen wrench, remove the four screws securing the board to the case and remove the Power Supply Board.

Replacement:

5. Ensure that the Power Supply Shield is secured to the case.
6. Reinstall the Power Supply Board in reverse order ensuring that the self-locking screws seat fully.

   Caution: Over tightening screws may damage pump housing.

Adjustment/ Verification:

7. Perform the 12.0 Volt Power Supply Test, 6.5.2 of section 6.5.
8. Close the case.
9. Perform the Periodic Maintenance Procedure, section 3.1.

Parent Board

Removal:

Caution: To avoid damage to electronic components and the risk of electrical shock, disconnect the pump from the AC power and remove the battery fuse before opening the case.

1. Open the case.
2. Grasp the Power Management and Common Boards at the plastic board extractor and pull straight out.
3. Grasp each of the three Microprocessor Boards at the plastic board extractor and pull straight out. Disconnect the Pump Module ribbon cables at connector P1 on each of the three Microprocessor Boards.
4. Unplug the DC Power connector J10 and the Rear Panel connector J9 from the Parent Board.
5. Unplug the three ribbon cable connectors from the Display Board.
6. Using a 7/64" Allen wrench, remove the six screws securing the Parent Board to the front case and remove the Parent Board.

Replacement:

7. Install the Parent Board with the six Allen head screws which were removed in step 6.

   Caution: Over tightening screws may damage pump housing.

8. Reconnect the three ribbon cables to the Display Board. Verify correct pin alignment of the connectors before proceeding.

   Caution: Fold the ribbon cables to the Display Board for plug-in board clearance. Do not press on the cables too firmly; this could cause electrical shorts between the component leads and the cable.

9. Connect the Rear Panel connector J9 and the DC Power connector J10 to the Parent Board.
10. Connect the Pump Module ribbon cable connectors to P1 on each of the Microprocessor Boards, align the boards between the top and bottom card guide ribs in the case, and press on the plastic board extractor to fully seat the boards into the mating connectors. Verify that the other end of the ribbon cable is fully mated to the Pump Module connectors.
11. Align the Common Board between the top and bottom card guide ribs in the case and press on the plastic board extractor to fully seat the board into the mating connector.

Parent Board (cont)

12. Align the Power Management Board between the top and bottom card guide ribs in the case and press on the plastic board extractor to fully seat the board into the mating connector.

13. Close the case.

Adjustment/ Verification:

14. Perform the Periodic Maintenance Procedure, section 3.1.

Main Battery

Removal:

1. Remove the battery fuse from the holder on the rear case.
2. Using a 1/16" Allen wrench remove the six screws securing the battery cover to the case.
3. Remove the Main Battery from the battery compartment enough to allow access to the battery connections.
4. Disconnect the two quick disconnect connectors from the ends of the battery and remove the Main Battery from the pump.

Replacement:

5. Orient the Main Battery with the positive (+) terminal to the right and connect the two quick disconnect connectors.
6. Dress wires to avoid pinching between the case and battery cover. Install the battery cover and secure with the six flat Allen head screws which were removed in step 2.

   Note: Screw holes will not align properly if the battery cover is upside down.

   Caution: Over tightening the screws may damage the battery cover or case.

7. Install the battery fuse and plug in the AC power cord.

Adjustment/ Verification:

8. Verify that the charge LED is on and allow the battery to charge for a minimum of 24 hours.
9. Unplug the AC power cord.
10. POWER on a channel. Press CHECK BAT and verify that the alphanumeric display reads *> 3 HOURS LEFT*.
11. In each of the 3 pump modules, install a properly primed IV set cassette with a solution container height of 6 to 24 inches above the cassette door, and close the door. Open the roller clamps.
12. Press the POWER buttons on the Control Panel to turn all 3 channels on. Set the flow rate on each channel to 888.8 ml/hr, press the INFUSE ALL switch on each channel, and press the INFUSE/PAUSE button to start an infusion.
13. Allow the pump to run until a Low Battery alert occurs. (This will take approximately 4.5 hours.) Verify that the pump has run at least 3 hours without a low battery alert.
14. Turn off all channels. Connect to AC power cord and allow the battery to reach full charge. Verify that the message >3 HRS LEFT scrolls across the display when the CHECK BAT key is pressed while one channel is turned on.

RAM Battery

Removal:

Caution: To avoid damage to electronic components and the risk of electrical shock, disconnect the pump from the AC power and remove the battery fuse before opening the case.

1. Open the case.
2. Grasp the Common Board at the plastic board extractor and pull straight out.
3. Remove RAM Battery BT1 from the coin battery holder.

Note: When BT1 is removed the user settings and the 8 hour memory is lost. After the battery is replaced, the user settings will revert to the following defaults:

Alarm Volume: Maximum
Pressure Limit: High
Rate Limit: All Rate
Flow Rate: 0.0
Volume To Be Infused: 0.0
Total Infused: 0.0

Replacement:

4. Install the RAM Battery into the coin battery holder with the + side out.
5. Align the Common Board between the top and bottom card guide ribs in the case and press on the plastic board extractor to fully seat the board into the mating connector.

Adjustment/ Verification:

6. Perform the RAM Battery Voltage Test, 6.3.1 of section 6.3.
7. Close the case.
8. Set the alarm volume, pressure limit, and rate limit as desired per the Operation Manual, Chapter 12.
9. Perform the Periodic Maintenance Procedure, section 3.1.

Speaker

Removal:

Caution: To avoid damage to electronic components and the risk of electrical shock, disconnect the pump from the AC power and remove the battery fuse before opening the case.

1. Open the case.
2. Using a 9/64" Allen wrench, remove the screw securing the Rear Panel Harness cable clamp to the left side of the case.
3. Using a 3/32" Allen wrench, remove the screws securing the Speaker to the case.
4. Cut the shrink tubing off the speaker terminals and unsolder the Rear Panel Harness wires.

Replacement:

5. Cut two pieces of 1/8 " shrink tubing 1/2" to 3/4" long and slide the shrink tubing onto the blue and white/blue wires on the Rear Panel Harness.
6. Solder the blue wire to the positive (+) Speaker terminal, and the white/blue wire to the negative (-) Speaker terminal.
7. Slide the shrink tubing over the soldered Speaker terminals and use a heat gun to shrink.

   Caution: Excessive heat may damage wire insulation or plastic pump components.

8. Attach the Speaker to the case using the four Allen head screws removed in step 3.
9. Secure the Rear Panel Cable Harness cable clamp to the mounting boss near the Speaker using the Allen head screw which was removed in step 2.
10. Close the case.

Adjustment/ Verification:

11. Perform the Periodic Maintenance Procedure, section 3.1.

Buzzer

Removal:

Caution: To avoid damage to electronic components and the risk of electrical shock, disconnect the pump from the AC power and remove the battery fuse before opening the case.

1. Open the case.
2. Using a 5/64" Allen wrench, remove the screws securing the Buzzer to the case.
3. Cut the shrink tubing off the Buzzer terminals and unsolder the Rear Panel Harness wires.

Replacement:

4. Cut two pieces of 1/8 " shrink tubing 1" long and slide the shrink tubing onto the red and white/red wires on the Rear Panel Harness.
5. Solder the red wire to the positive (+) Buzzer terminal, and the white/red wire to the negative (-) Buzzer terminal.
6. Slide the shrink tubing over the soldered Buzzer terminals and use a heat gun to shrink.

   Caution: Excessive heat may damage wire insulation or plastic pump components.

7. Attach the Buzzer and transorb ground terminal, trapping the ESD shield between the Buzzer and the case. The transorb is the short wire coming off the quick disconnect connector. The ground terminal should be positioned above the right mounting ear of the Buzzer. Use the two Allen head screws, which were removed in step 2, to secure these parts.

Adjustment/ Verification:

8. Perform the ESD Suppressor Check, 6.5.1 of section 6.5.
9. Close the case.
10. Perform the Periodic Maintenance Procedure, section 3.1.

Front Case

Removal:

Caution: To avoid damage to electronic components and the risk of electrical shock, disconnect the pump from the AC power and remove the battery fuse before opening the case.

1. Open the case.
2. Using a 1/8" Allen wrench, remove the three pump module retaining screws from the bottom of the case and remove the Pump Modules.

   Note: Push on the motor bracket to remove the Pump Module out through the front of the pump case. Considerable force may need to be applied to overcome the drip seal friction.

3. Unplug the ribbon cables from the Pump Module Interface boards.
4. Grasp the Power Management and Common Boards at the plastic board extractor and pull straight out.
5. Grasp the Microprocessor boards at the plastic board extractor and pull straight out.
6. Unplug the DC Power connector J10 and the Rear Panel connector J9 from the Parent Board.
7. Unplug the three ribbon cable connectors from the Display Board.
8. Using a 7/64" Allen wrench, remove the six screws securing the Parent Board to the front case and remove the Parent Board.
9. Using a 1/4" nut driver, remove the four 1/4" hex nuts with captive lock washers securing the Control Panel/Display Assembly to the front case and remove the assembly from the pump.
10. Using a 11/32" nut driver, remove the nut with captive lock washer from the front case ground stud in the upper right corner.
11. Remove the Rear Panel Harness ground wire terminal from the front case ground stud.
12. Using a 9/64" Allen wrench, remove the screw and lock washer securing the Rear Panel Harness cable clamp to the long front case mounting boss and separate the case halves.
13. Using a 11/32" nut driver, remove the remaining hex nut with captive lock washer from the front case ground stud.
14. Remove the pump module ground wire terminal from the front case ground stud and the lock washer underneath the wire.
15. Remove the foam tape securing the pump module ground wire to the side of the case.

16. Using a 1/2" nut driver, remove the hex nuts securing the pump module ground terminals to the bulkhead fittings. Disconnect the ground wire from the bulkhead fitting and remove the washer and bulkhead fitting.

    Note: Use a 5/8" wrench to hold the bulkhead fitting hex to prevent rotating and damaging the ground terminals.

17. Using a 7/64" Allen wrench, remove the screws and lock washers securing the rubber feet to the case.

Replacement:

18. Attach the rubber feet to the bottom of the case with the Allen head screws and lock washers which were removed in step 17.

    Caution: Do not over-tighten screws to prevent distortion of feet.

19. Place the three pump module bulkhead fittings through the three holes in the bottom of the case from the outside.

20. Install the pump module ground wire terminals over the threaded portion of each of the bulkhead fittings so that the loose wire runs up the right side of the case as viewed from the inside.

21. Secure the terminals using the internal tooth lock washers and 1/2" hex nuts which were removed in step 16.

    Note: Use a 5/8" wrench to hold the bulkhead fitting hex to prevent rotating and damaging the ground terminals.

22. Install the internal tooth lock washer, which was removed in step 14, on the front case ground stud in the upper right corner of the case. Install the pump module ground wire terminal on the ground stud and secure using the 11/32" hex nut which was removed in step 13.

23. Position the ground wire into the corner of the case so that the channel 1 Pump Module circuit board will not rub on it. Remove the adhesive liners from two pieces of foam tape and secure the pump module ground wire to the side of the case with one piece of tape above the lower right case alignment rib and one below the rib.

24. Secure the Rear Panel Harness cable clamp to the long front case mounting boss with the Allen head screw and lock washer which were removed in step 12.

25. Install the Rear Panel Harness ground terminal on the front case ground stud and secure with the 11/32" hex nut which was removed in step 10.

26. Install the Control Panel/Display Board Assembly on the front case and secure with four 1/4" hex nuts which were removed in step 9.

27. Install the Parent Board ensuring that the six Allen head screws, which were removed in step 8, are fully seated.

    Caution: Over-tightening screws may damage the pump housing.

28. Connect the three ribbon cables to the Display Board. Verify correct pin alignment of the connectors before proceeding.

    Caution: Fold ribbon cables flat against the Display Board for plug-in board clearance. Do not press on the cables too firmly; this could cause electrical shorts between the components leads and the cable.

29. Connect the Rear Panel connector J9 and the DC Power connector J10 to the Parent board.

30. Align the Microprocessor boards between the top and bottom card guide ribs in the case and press on the plastic board extractor to fully seat the boards into the mating connectors.

31. Align the Common board between the top and bottom card guide ribs in the case and press on the plastic board extractor to fully seat the board into the mating connector.

32. Align the Power Management board between the top and bottom card guide ribs in the case and press on the plastic board extractor to fully seat the board into the mating connector.

33. Connect the ribbon cables to the Pump Module Interface Board connectors.

34. Install the Pump Modules and secure with the flat Allen head screws which were removed in step 2.

35. Verify that the other ends of the ribbon cables are fully mated to the Microprocessor Board connectors.

Adjustment/ Verification:

36. Perform the ESD Suppressor Check, 6.5.1 of section 6.5.

37. Close the case.

38. Perform the Periodic Maintenance Procedure, section 3.1.

Rear Case

Removal:

Caution: To avoid damage to electronic components and the risk of electrical shock, disconnect the pump from the AC power and remove the battery fuse before opening the case.

1. Open the case.
2. Grasp the Channel 1 Microprocessor Board at the plastic board extractor and pull straight out. Disconnect the Pump Module ribbon cable from the Microprocessor Board connector P1.
3. Using a 9/64" Allen wrench, remove the screw and lock washer securing the Rear Panel Harness cable clamp to the long front case mounting boss.
4. Unplug the DC Power connector J10 and the Rear Panel connector J9 from the Parent Board.
5. Using a 11/32" nut driver, remove the hex nut with captive lock washer from the front case ground stud in the upper right corner.
6. Remove the Rear Panel Harness ground wire terminal from the front case ground stud and separate the case halves.
7. Using a 7/64" Allen wrench, remove the two screws and lock washers securing the Power Cord retainer to the rear case.
8. Unplug the Power Cord from the pump AC Receptacle.
9. Using a 1/16" Allen wrench, remove the six screws securing the battery cover to the case.
10. Remove the Main Battery from the battery compartment enough to allow access to the battery connections.
11. Disconnect the two outside quick disconnect connectors from the battery and remove the Main Battery from the pump.
12. Feed the wires used to connect the battery through the slots in the back of the battery compartment.
13. Remove the bottle hanger retaining rings and bottle hangers.
14. Remove the tube gasket from the groove around the perimeter of the case.
15. Cut the five cable ties securing the wiring to the case.

    Note: Do not cut the two screw mounted cable ties which attach the Rear Panel Harness to the upper left of the case and the Power Supply ground wire to the upper right of the case.

16. Disconnect Power Supply secondary connector J2, primary connector J1 and ground quick disconnect P1.

17. Using a 7/64" Allen wrench, remove the four screws securing the board to the case and remove the Power Supply Board.

18. Using a 7/64" Allen wrench, remove the screw and lock washer securing the Power Supply ground wire cable clamp to the case.

19. Remove the two nylon screws securing the Power Supply shield to the case.

20. Using a 1/8" Allen wrench, remove the four screws securing the Pole Clamp Assembly to the case.

21. Using a 9/64" Allen wrench, remove the screw and lock washer securing the Rear Panel Harness cable clamp to the left side of the case.

22. Using a 9/64" Allen wrench, remove the screw and lock washer securing the AC ground wire terminal to the right side of the case ground strap.

23. Using a 9/64" Allen wrench, remove the screw and lock washer securing the ground wire terminals to the left side of the case ground strap and remove ground strap.

24. Using a 9/64" Allen wrench, remove the screw and two lock washers securing the AC Receptacle ground wire terminal to the case.

25. Using a 3/32" Allen wrench, remove the screws and lock washers securing the AC Receptacle to the case.

26. Disconnect the quick disconnect terminal from the Battery Fuse holder.

27. Using a 9/16" deep well socket, remove the hex nut securing the Battery Fuse holder to the case.

28. Using a 5/64" Allen wrench, remove the screws and lock washers securing the Buzzer to the case and remove the ESD shield.

29. Using a 1/2" socket, remove the hex nut and washer securing the Nurse Call jack to the case.

30. Remove the protective cap from the communications port connector. Using a 1/16" Allen wrench, remove the screws securing the communications port connector to the case and the nuts and lock washers located on the inside of the case. Do not remove the gasket attached to the communications port connector.

31. Using a 5/16" nut driver, remove the hex nut securing the Lockout Switch to the case.

32. Using a 3/32" Allen wrench, remove the screws and lock washers securing the Speaker to the case and remove the Rear Panel Harness from the case.

33. Using a 7/64" Allen wrench, remove the screws and lock washers securing the rubber feet to the case.

Replacement:

34. Attach the rubber feet to the bottom of the case with the Allen head screws and the internal tooth lock washers which were removed in step 33.

    Caution: Do not over-tighten screws to prevent distortion of feet.

35. Starting at the bottom center of the case, install the 38.75" tube gasket in the groove around the perimeter of the case. Trim off excess if ends overlap.

36. Attach the Rear Panel Harness Speaker to the case back with wires pointing down. Secure using the four Allen head screws and the four internal tooth lock washers which were removed in step 32.

37. Slide the large terminal on the lockout switch ground cable over the threaded portion of the Lockout Switch, then insert the switch in the case mounting hole. From the outside of the case secure the Lockout Switch using the 5/16" hex nut which was removed in step 31. Apply 1 drop of Loctite 290 threadlocker to the switch thread after installing the nut.

    Caution: Do not get Loctite into the switch plunger. This will damage the Lockout Switch.

38. Remove the adhesive liner from the Communication Port gasket, if replacement is necessary, and attach the gasket to the front face of the Communication Port connector. Position the Communication Port connector in the mounting hole and secure with the two button head screws, the internal tooth lock washers, and the nuts which were removed in step 30. Install the screws from the outside of the case. Attach the end ground terminal, coming from the Nurse Call jack, between the lock washer and the right mounting ear of the Communication Port connector. Orient with the wire pointing down. Install the protective cover on the communications port connector.

39. Insert the Nurse Call jack in the case mounting hole, and from the outside of the case secure with the nut and the washer which were removed in step 29.

40. Center the Buzzer ESD shield over the Buzzer mounting area.

41. Attach the Buzzer and transorb ground terminal, trapping the ESD shield between the Buzzer and the case. The transorb is the short wire coming off the quick disconnect connector. The ground terminal should be positioned above the right mounting ear of the Buzzer. Use the two Allen head screws and the internal tooth lock washers, which were removed in step 28, to secure these parts.

42. Feed the Battery Fuse holder cable assembly through the mounting hole from the outside of the case. Place the nut, which was removed in step 27, onto the assembly and tighten using a 9/16" deep well socket.

43. Connect the Rear Panel Harness black wires with the quick disconnect terminal to the tab on the Battery Fuse holder.

44. Feed the AC Receptacle assembly, oriented with the Receptacle center ground terminal at the bottom, through the mounting hole from the outside of the case and secure using the two Allen head screws and the internal tooth lock washers which were removed in step 25.

45. Attach the AC Receptacle short ground wire terminal to the case ground boss to the left of the AC Receptacle. Secure the ground wire using the Allen head screw and the two internal tooth lock washers, which were removed in step 24, one on each side of the terminal.

46. Position the ground strap to line up with the two ground bosses in the center of the case above the battery compartment.

47. Secure the loose ground terminal from the Rear Panel Harness, along with the loose terminal from the Power Supply ground wire, the loose terminal from the Lockout Switch ground, and the Nurse Call jack ground terminal to the left side of the ground strap using the Allen head screw and the internal tooth lock washer which were removed in step 23. Terminal order and orientation is not critical except for the Power Supply ground wire which must be oriented to the right.

48. Secure the long AC Receptacle ground wire terminal to the right side of the ground strap using the Allen head screw and the internal tooth lock washer which were removed in step 22.

49. Secure the Rear Panel Harness cable clamp to the mounting boss near the Speaker using the Allen head screw and the internal tooth lock washer which were removed in step 21.

50. Position the Pole Clamp assembly so that the mounting holes line up with the holes in the case and the pivot rests in the recess in the back of the case. Secure the Pole Clamp Assembly from the inside using the four flat Allen head screws which were removed in step 20.

51. Position the Power Supply Shield to line up with the two mounting bosses inside the case to the right of the Pole Clamp. Secure using the two nylon screws which were removed in step 19.

52. Secure the Power Supply ground wire cable clamp to the case at the right mounting boss above and closest to the battery compartment using the Allen head screw and the internal tooth lock washer which were removed in step 18.

53. Secure the Power Supply board using the four Allen head screws, which were removed in step 17, ensuring that the self-locking screws seat fully.

Caution: Over-tightening screws may damage pump housing.

54. Connect Power Supply secondary connector J2, primary connector J1 and ground quick disconnect P1.

55. Dress the wiring cables even with the surface of the battery compartment. Secure wires in place with cable ties through the four holes around the edge of the battery compartment and the stick on cable tie mount.

56. Insert the Bottle Hangers into the mounting holes in the handle area of the case.

57. Install retaining rings, which were removed in step 13, onto Bottle Hanger retaining grooves to secure hangers in place.

58. Feed the wires used to connect the battery through the slots in the back of the battery compartment. Feed the two black wires from the fuse holder through the right slot, and the two red wires from the Rear Panel Harness through the left, as viewed from the inside of the case.

59. Orient the Main Battery with the positive (+) terminal to the right and connect the quick disconnect connectors.

60. Dress wires to avoid pinching between the case and battery cover. Install the battery cover and secure with six flat Allen head screws which were removed in step 9.

    Note: Screw holes will not align properly if the battery cover is upside down.

    Caution: Over-tightening the screws may damage the battery cover or case.

61. Connect the Power Cord to the pump AC receptacle.

62. Secure the Power Cord retainer to the case with the two Allen head screws and lock washers which were removed in step 7.

    Caution: Over-tightening the screws may damage the case.

63. Secure the Rear Panel Harness cable clamp to the long front case mounting boss with the Allen head screw and lock washers which were removed in step 3.

64. Install the Rear Panel Harness ground terminal on the front case ground stud and secure with the 11/32" hex nut which was removed in step 5.

65. Connect the Rear Panel connector J9 and the DC Power connector J10 to the Parent board.

66. Connect the Pump Module ribbon cable connector to P1 of Channel 1 Microprocessor Board.

67. Align the Channel 1 Microprocessor Board between the top and bottom card guide ribs in the case and press on the plastic board extractor to fully seat the board into the mating connector.

68. Verify that all the circuit boards are fully seated, that the ribbon cables connecting the Pump Modules to the Microprocessor Boards are fully seated, and that all wires are dressed such that they do not interfere with any moving parts in the pump and are clear of pinch points when the case halves mate.

69. Clean the case with alcohol where the Instruction Label is to be installed. Type the serial number and model on a piece of white paper. Trim the paper slightly larger than the window on the Instruction Label. Remove the backing from the Instruction Label and center the serial number in the window. Install the Instruction Label in the same position as on the old case.

Adjustment/ Verification:

70. Perform the Rear Case Tests, section 6.5.

71. Close the case.

72. Perform the Periodic Maintenance Procedure, section 3.1.

Power Cord

Removal:

1. Using a 7/64" Allen wrench, remove the two screws and lock washers securing the Power Cord retainer to the case.
2. Unplug the Power Cord from the pump AC receptacle.

Replacement:

3. Connect the Power Cord to the pump AC receptacle.
4. Secure the Power Cord retainer to the case with the two Allen head screws and lock washers which were removed in step 1.

   Caution: Over tightening the screws may damage the case.

Adjustment/ Verification:

5. Connect the pump to AC power. Verify that the CHARGE indicator on the front panel illuminates.
6. Perform the AC Line Leakage Test, 3.1.15 of section 3.1.
7. Perform the Ground Continuity Test, 3.1.16 of section 3.1.